



# **NAVAL POSTGRADUATE SCHOOL**

**MONTEREY, CALIFORNIA**

## **THESIS**

**INVESTIGATING TEAM COLLABORATION OF AN AIR  
FORCE RESEARCH EVENT  
OCTOBER 2008**

by

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June 2009

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**INVESTIGATING TEAM COLLABORATION OF AN  
AIR FORCE RESEARCH EVENT OCTOBER 2008**

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## **ABSTRACT**

During October 2008, an Air Force Research Event was conducted to integrate operational concepts and training techniques from different commands. The collaborative teamwork demonstrated in the highly asymmetric threat exercise scenario was recorded in Mardem-Bey internet relay chat logs across fifteen different chat rooms. The goal of this thesis was to use chat room recorded data that was extracted from an exercise environment simulating an air and space operations center (AOC) cell using an experimental structure; non-approved tactics, techniques, and procedures; and a fictional environment to stimulate certain training processes to evaluate a measurement model of macrocognition developed under the Collaboration and Knowledge Integration program, sponsored by the Office of Naval Research. The model focuses on team member's cognitive processes used during collaboration with the goal of trying to understand how individuals collaborate to build new knowledge and accomplish their tasks. Effective chat communications may expedite the process of moving the team towards achieving their ultimate goal, which was to produce optimum combat effectiveness in a timely manner. Thesis results will be provided to the Office of Naval Research to help improve collaboration among teams while operating in stressful and dynamic environments.

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## **LIST OF ACRONYMS AND ABBREVIATIONS**

AFB	Air Force Base
AOC	Air and Space Operations Center
CFACC	Combined Force Air Component Commander
COA	Course Of Action
DEC	Dynamic Effects Cell
DTC	Dynamic Targeting Cell
ECF	Extra Code Filler
ECSA	Externalized Cue Strategy Association
F2T2EA	Fix, Find, Track, Target, Engage, Assess
IED	Improvised Explosive Device
IIG	Individual Information Gathering
IIS	Individual Information Synthesis
ISR	Intelligence, Surveillance, Reconnaissance
ISRC	Intelligence, Surveillance, Reconnaissance Cell
ISRD	Intelligence, Surveillance, Reconnaissance Division
ITK	Individualized Team Knowledge
JADOCs	Joint Automated Deep Operations Coordination System
JFACC	Joint Forces Air Component Commander
JFC	Joint Force Commander
MARLO	Marine Liaison Officer
MIO	Maritime Interdiction Operations
MURI	Multidisciplinary University Research Initiative
NALE	Naval Aviation Liaison Element
NEADS	Northeast Air Defense Sector
NORAD	North America Aerospace Defense Command
ONR	Office of Naval Research
PRTA	Pattern Recognition and Trend Analysis
RTA	Request Take Action
SADO	Senior Air Defense Officer
SIDO	Senior Intelligence Duty Officer



SODO	Senior Offensive Duty Officer
SOLE	Special Operations Liaison Element
SUMMIT	Systems for Understanding and Measuring Macrocognition in Teams
TENA	Team Evaluation and Negotiation of Alternatives
TIE	Team Information Exchange
TKS	Team Knowledge Sharing
TSOG	Team Solution Option Generation
TST	Time-Sensitive Target
UR	Uncertainty Resolution

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# **I. INTRODUCTION**

## **A. THESIS GOAL**

### **1. Collaboration and Knowledge Interoperability**

The Department of Defense is being confronted by a highly capable and quickly adaptable adversary. The adversary fights in a constantly changing and dynamic environment using asymmetrical warfare techniques. In order to effectively combat and defeat such an enemy, human decision makers at the tactical, operational and strategic levels must act and decide rapidly. To enable personnel to make quicker and more accurate decisions, personnel at all levels of the chain of command must be given access to more detailed information than ever before and collaborate with several inter-theater and cross border multinational and multiagency personnel.

The Office of Naval Research (ONR) sponsored Collaboration and Knowledge Interoperability program attempts to gain insight and understanding into the human cognitive processes demonstrated during an individual's (or group of individuals) attempt at solving extremely complex, time sensitive, and dynamic problems. ONR studies suggest that by gaining greater insight and understanding of all the metacognitive and macrocognitive processes exhibited by humans during the entire decision making process, better system architectures, models and methods can be developed to improve the reliability and speed of data dissemination to the human decision maker. Additionally, creation of human agent interfaces based on human factor principles would provide better information displays to increase user understanding and ease of system use therefore improving effectiveness of decision making (Letsky, 2008).

ONR developed a model of team collaboration and cognitive processes (Figure 1) that includes the input factors (time pressure, information uncertainty, dynamic environment factors, etc...), and phases (knowledge construction, collaborative team problem solving, team consensus, and outcome evaluation and revision) demonstrated during team collaboration.

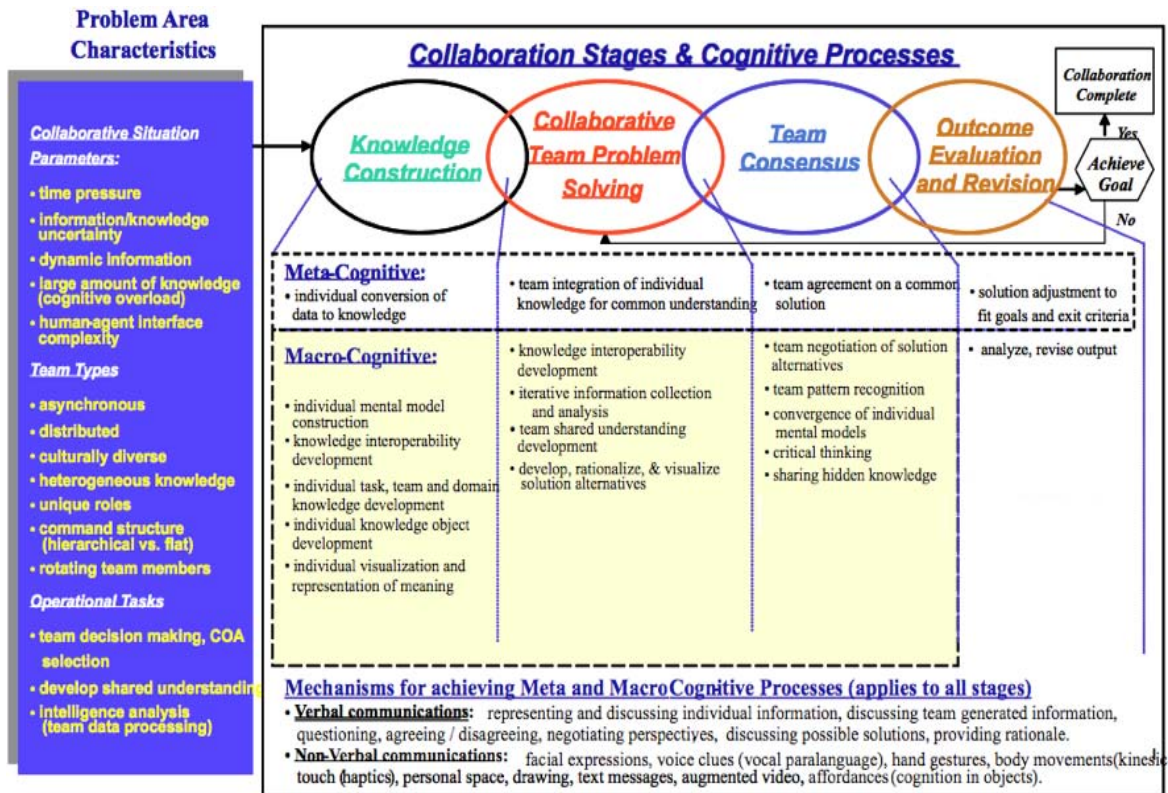


Figure 1. Collaboration Stages and Cognitive Process Model (From Warner, Letsky, & Cowen, 2005).

The Model of Team Collaboration, shown in Figure 1, allows researchers the ability to try and predict human decision-making outcomes in specific real-world events and exercise scenarios (Warner, Letsky, & Cowan, 2005).

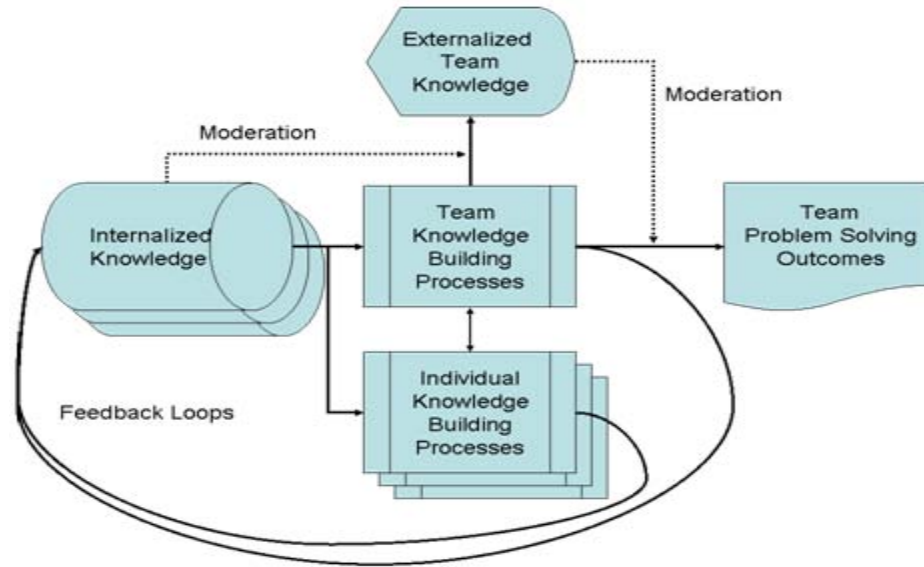
## 2. Goals for the SUMMIT MURI Research

In October 2008, an evolutionary change to the original Model of Team Collaboration was suggested during the Office of Naval Research Systems for Understanding and Measuring Macro cognition in Teams (SUMMIT) meeting sponsored by a Multidisciplinary University Research Initiative (MURI) grant. The evolutionary changes were needed to address human related collaboration issues that have been discovered as the Department of Defense steadily increases its reliance and dependence on network centric warfare. Network centric warfare requires strong communication and detailed coordination among all operational and tactical units located within or outside

the operational theater. For network centric warfare to be successful several geographically separated operational and tactical personnel must be able to quickly form into a cohesive team. Despite possible individual biases, the team must be able to effectively share and process information (convert data to information and information to knowledge) in order to facilitate faster decision making and effectively combat the enemy. The MURI team conducted detailed research and investigated how the delivery, availability and different types and information and information processing systems affected the macrocognitive processes within teams that were both centrally located and distributed. The MURI research goal is to improve collaboration process understanding and creation of better tools to better support macrocognition in teams. Additionally, the research focused on creating a test environment and produced network centric warfare cognitive metrics that can be used to evaluate team cognitive behavior (Fiore, Rosen, Salas, Burke, Warner, & Letsky, in press).

### **3. Major Goals for This Thesis**

The major goal of this thesis is to evaluate the new Office of Naval Research sponsored Measurement Model for Macrocognition Research using the new SUMMIT coding definitions, dated October 2008. Definitions of the macrocognitive processes included in the model were applied to the Research Event Air and Space Operations Center Dynamic Effects Cell generated data. Figure 2 is a graphical representation of the measurement model metacognitive phases and illustrates how individuals functioning as a team process and learn new information. The new SUMMIT coding definitions will be discussed in detail in Chapter IV of this thesis and the coding process will be explained in Chapter V of this thesis.



Legend:

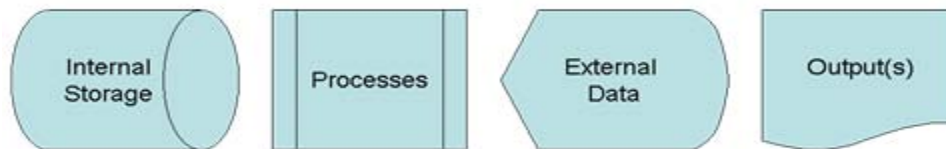


Figure 2. Measurement Model for Macrocognition Research (After Fiore et al., in press).

The October 2008 Research Event provides us with a realistic, dynamic, time-sensitive situation to assess and validate the measurement model. By coding the data from the exercise utilizing to the new SUMMIT definitions, we can determine if the metacognitive processes shown in the measurement model (Figure 2) are an actual representation of how teams collaborate to handle dynamic problems in a time sensitive environment.

During coding, it was discovered that there were existing gaps in the measurement model and the SUMMIT definitions. Theses gaps are explained in Chapter VI, results section of this thesis, along with recommendations to the definitions. Additionally, some of the SUMMIT definitions were not used during our coding of the Research Event data. A brief explanation of why certain codes weren't used is included in Chapter VI.

#### 4. Goals for the AOC Dynamic Effects/Targeting Cell

The main goals of the Air Force Research Event are listed in Table 1. For the purpose of this thesis the terms Dynamic Effects Cell (DEC) and Dynamic Targeting Cell (DTC) are synonymous.

Table 1. Air Force Research Event Dynamic Effects Cell Research Objectives  
(From Air Force Research Laboratory Warfighter Readiness Division, 2008).

Air Force Research Event Dynamic Effects Cell Research Objectives
Goal #1: Assess effects of chat protocol on communications and mission performance: <ul style="list-style-type: none"><li>- Measure effectiveness of chat room user</li><li>- Measure of efficient times from info drop to engagement</li></ul>
Goal #2: Highlight and explore future concepts for continuous learning: <ul style="list-style-type: none"><li>- Use individual training sessions to train in Air and Space Operations Center environment.</li><li>- Assess war fighter planning, employment and effectiveness</li></ul>
Goal #3: Integrate war fighter controllers and information simulation exercise participants: <ul style="list-style-type: none"><li>- Build and employ Master Scenario Event List and Request For Information management environment.</li><li>- Engage Senior Intelligence Duty Officer and Target Duty Officer with realistic interactions and survey for effect</li></ul>
Goal #4: Use of multiple performance measurement systems
Goal #5: Assess effects of IED Network Defeat Tactics, Techniques and Procedures for non-kinetic mission execution

This thesis evaluated the team collaboration within the Air and Space Operations Center (AOC) DEC, which is a contributing factor for measuring the effectiveness of all the Air Force Research Event research goals.



## **B. AIR AND SPACE OPERATIONS CENTER DYNAMIC EFFECTS/TARGETING CELL**

### **1. Mission**

After five years in Afghanistan and Iraq, the United States and Coalition forces remain actively engaged against a highly capable and adaptive enemy. Unlike the Cold War standoff with the Soviet Union that matched nation against nation, massive force against massive force, and military technology against military technology, today's enemy does not fight for a particular country, has no visible army to call its own, and has very limited technology, capabilities and resources to combat coalition forces. The enemy does however have a very strong will to fight and the means by which to use irregular warfare techniques to create mass fear and to disrupt the life of those friendly to the United States' way of life. The enemy's employment of improvised explosive devices (IEDs) has caused massive fear, severe damage, and the loss of life of several sailors, soldiers, and countless Iraqi civilian personnel. To counter the IED threat and take advantage of the limited targeting window provided by those responsible for IED employment, new ways have been adapted by the AOC to quickly and accurately conduct dynamic targeting against the enemy and IED threats.

The employment of the dynamic effects/targeting cell process against IED networks is currently being researched by the Air Force Research Laboratory in collaboration with the USAF Warfare Center. Adaptation of a dynamic effects cell within the AOC (Joint and Combined) command structure, Figure 3, would provide the Joint Force Air Component Commander (JFACC) the leverage to engage and attack targets of opportunity that meet Joint Force Commanders mission objectives. Dynamic targeting is a means by which coalition forces could possibly respond to the employment of IEDs and insurgent network leadership located within Afghanistan and Iraq. Due to the short time-sensitive nature, dynamic targets are normally vetted quickly and accurately through the targeting cycle. This process allows the JFACC to task available assets or reassign assets to engage and destroy known targets or other potential threats at a moment's notice. The limited time window available for target engagement and

destruction means that coalition forces must be prepared to apply timely and accurate measures and counter-measures against the enemy.

## **2. Dynamic Effects Cell Area of Responsibilities**

The DEC would be responsible for directing the planning and coordination of all dynamic targets, time-sensitive targets (TSTs), and high payoff target operations (U.S. Air Force Central Command, no date). Currently, highly trained personnel and the advances in intelligence, surveillance and reconnaissance (ISR) assets provide the necessary tools to find, fix, target, track, engage, and assess targets of opportunity that require immediate attention and/or action. The airborne warning and control system, joint surveillance targeting attack radar system and unmanned aerial vehicles continue to provide the Commander of U.S. Central Command and the Combined Force Air Component Commander (CFACC) the means to destroy TSTs, such as IEDs, key insurgent leadership personnel, and terrorist network cells. Of the 3500 targets nominated by the CFACC during Operation Iraqi Freedom, 156 were classified as TSTs and 686 were identified as dynamic targets (Moseley, 2003).

## **3. Typical Operational Components and Players**

The DEC, if employed operationally, would fall within the Combat Operations Division of the AOC. Dynamic target nomination is coordinated with the combat operations division via the Senior Offensive Duty Officer (SODO). The organization makeup depends on the overall operational requirements and Joint Force Commander (JFC) mission objectives. If included as a component of the AOC, the DEC at a minimum would include a DEC Chief, a Deputy DEC Chief, a Ground Track Coordinator, an Attack Coordinator, and a Target Duty Office as shown in Figure 3 (U.S. Air Force Central Command, in press). Proper synchronization of ISR collection support for target tracking and engagement between the Senior Intelligence Duty Officer (SIDO) and DEC would be vital for overall AOC mission success and for de-confliction of friendly fires.

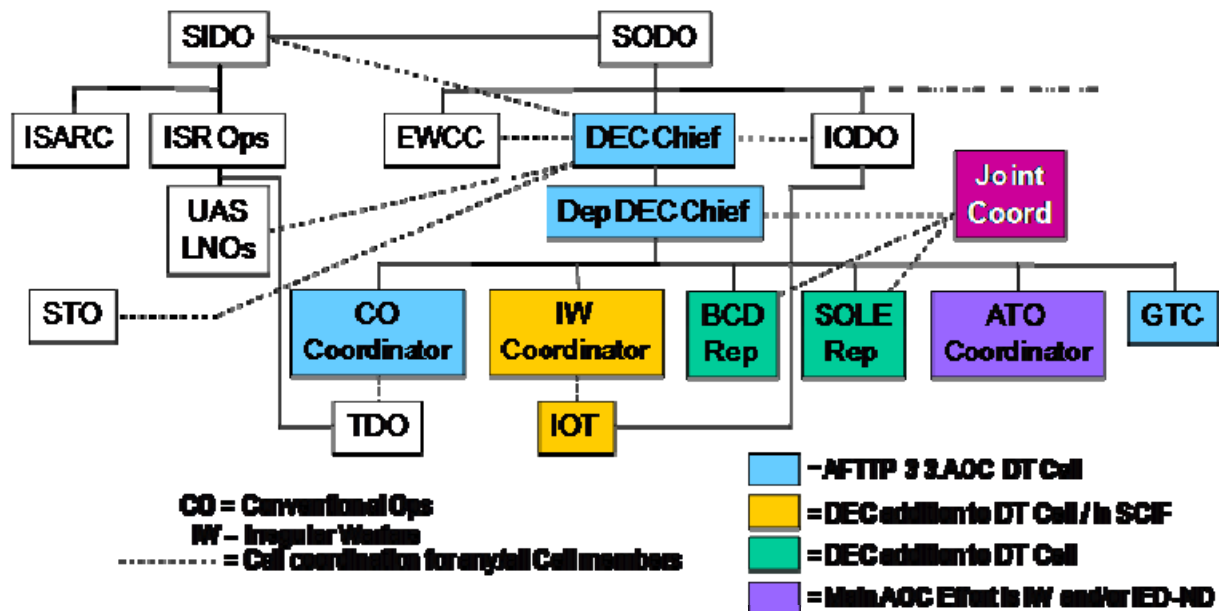


Figure 3. Dynamic Effects Cell Organizational Structure (From U.S. Air Force Central Command, in press).

#### 4. AOC Organization and Responsibilities

Today's AOC is the focal point from which planning, directing, controlling and coordinating of air and space operations comes together to satisfy the JFC objectives. The AOC must be prepared to carry out deliberate dynamic targeting without compromising its capability to conduct other major air combat operations (U.S. Air Force Central Command, no date). According to the Air Force Instruction 13-1 AOC Volume 3, a typical AOC command structure will consist of an AOC Director, five divisions (Strategy, Combat Plans, Combat Operations, Intelligence Surveillance and Reconnaissance, and Air Mobility), and multiple support specialty teams. Although not all inclusive, such a command structure is extremely vital to AOC mission success.

#### 5. Joint Force Air Component Commander Responsibilities

The JFACC is assigned by the JFC to manage the air war in theater. The JFACC is responsible for effective planning, coordination, allocation, and theater tasking of assets to accomplish the JFC mission (Joint Publication 3-30, 2003). The JFACC accomplishes the assigned mission in accordance with the guidance and under the

authority granted by the JFC. The JFACC exercises operational and tactical control over all assigned air assets and personnel located within the theater of operation. The allocation of assets to destroy key enemy leadership, suppression of enemy air defense systems, convoy protection, close air support, and dynamic targeting are just a few of many ways by which the JFACC could use the assigned assets to render an adversary's method of attack ineffective and thereby minimize damage and coalition force and civilian casualties.

### **C. AIR FORCE RESEARCH EVENT**

During October 2008, an intense Air Force Research Event was conducted bringing together several key operational command and control military and civilian personnel from all services. The event brought together personnel from the United States Air Force Warfare Center, Naval Strike Air Warfare Center, Special Operations Command, and United States Army (Air Force Research Laboratory Warfighter Readiness Division, 2008). The purpose of this Research Event was to assess tactics, techniques and procedures of operational command personnel performing kinetic and non-kinetic dynamic targeting in a highly asymmetric environment.

The Research Event was a simulation of a 12-hour overnight shift in the dynamic effect cells of a typical AOC. The 12-hour shift was broken into six 2-hour time sections. The operational players were separated during the exercise by use of false walls (i.e., room dividers) to simulate real-world space and time disparity of the various joint service personnel.

Communication between the various players was facilitated by the use of the Joint Automated Deep Operations Coordination System (JADOCS). JADOCS provides the warfighter with a timely, accurate, detailed battlespace view for planning, coordination, and execution of targets. It is a joint mission management software application that provides a suite of tools and interfaces for horizontal and vertical integration across battlespace functional areas (Raytheon Company, 2008). The Research Event communications were recorded across fourteen different chat room channels. Figure 4 identifies the chat rooms and specific personnel inside each chat room.

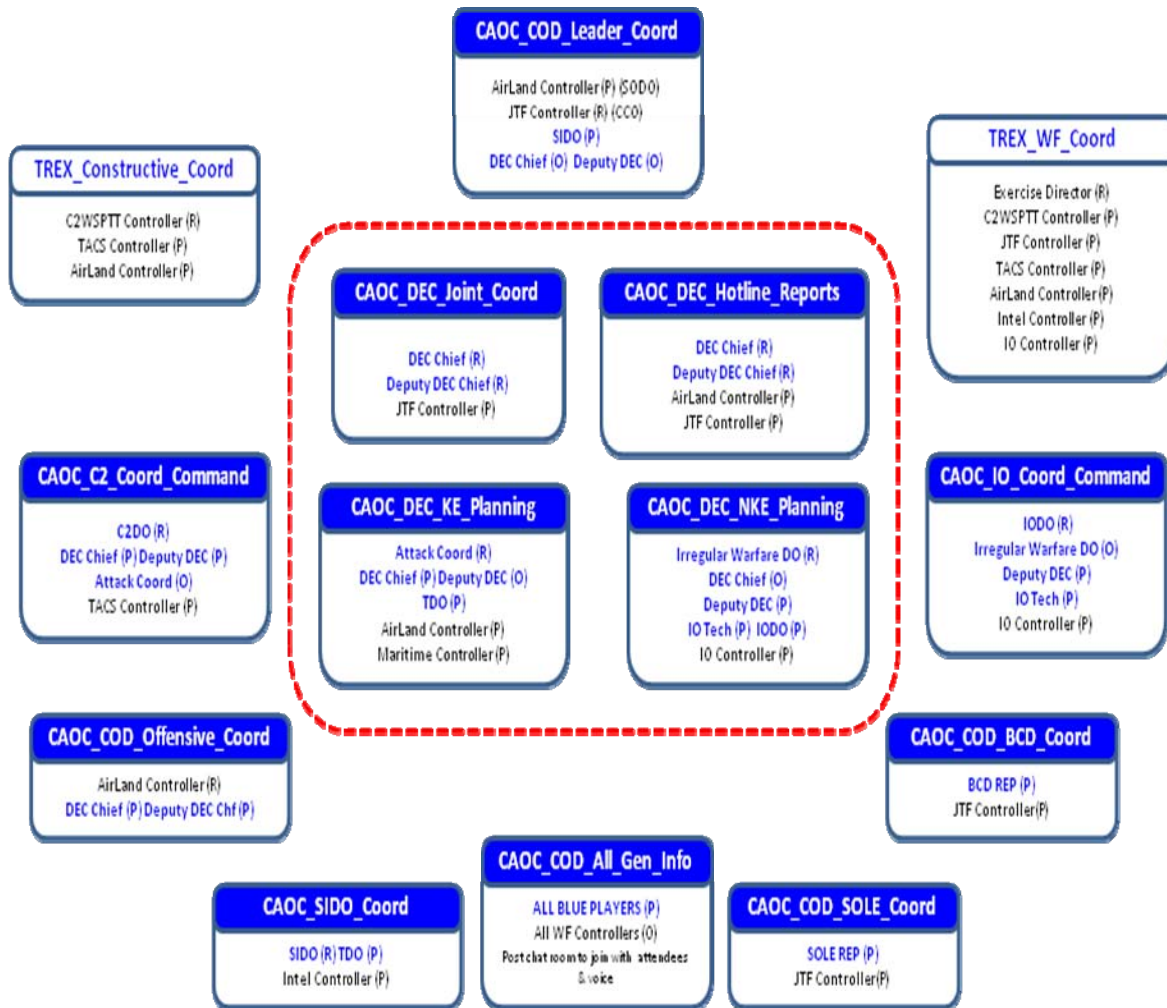


Figure 4. Chat Room Layout (From Air Force Research Laboratory Warfighter Readiness Division, 2008).

Each of the Research Event operational players had varied access and responsibilities in the chat rooms used for the exercise. All the operational players did not have access to every individual chat room. Some key operational players were designated as room owner (“R”), active participant (“P”) and/or observer (“O”). Figure 5 is a list of participants and their associated responsibilities in each chat room.

Blue Force Players												
	SIDO	C2 Duty Officer	DEC Chief	DEC Deputy Chief	Conv Ops Coordinator	Target Duty Officer	Irregular Warfare Coord	IO Targeteer	IO Duty Officer	DEC SOLE Rep	DEC BCD Rep	
White Force Players												
	Exercise Director	JOC JCE (JIF Controller)	BCD Fires (JTF Controller)	TI AMPC (JTF Controller)	NALE (JTF Controller)	IDO (Intel Controller)	ISRDTgts (Intel Controller)	DTRA (Intel Controller)	NTM (Intel Controller)	IO Controller (ST) IO Controller	CCO (AirLand Controller)	SODO (AirLand Controller)
											EWCC (AirLand Controller)	CASDO (AirLand Controller)
											ASOC (AirLand Controller)	SOLE Dir (SOF Controller)
											JSOTF J-3 (SOF Controller)	JSOTF JFE Dir (SOF Controller)
											Mojo SD (C2WSPTT Controller)	DkStr SD (C2WSPTT Controller)
											Active Room Users	Matrix Participants
											Room Observers	
Blue Force IRC Chat Rooms												
IADCCS Stakeholder/ Observer	S	S	O	S	S	O	S	O	S	S		
TBMCs Stakeholder/ Observer	O	O	O	O	O	O	O	O	O	O		
F_CAOC_COD_Leader_Coord	P	P										6
F_CAOC_C2_Coord_Command		R	P	P	P							7
F_CAOC_SIDO_Coord	R											7
F_CAOC_ISROPS_Coord	P											7
F_CAOC_COD_Offensive_Coord			P	P	O							7
F_CAOC_DEC_Joint_Coord			R	P	P							4
#_IED_Hotline_Reports	P		P	R								6
F_CAOC_DEC_KE_Planning			O	P	R	P*						8
F_CAOC_DEC_NKE_Planning			O	P								7
F_CAOC_IO_Coord_Command	O	P	P	P								9
#_JSOTF_Coord_Command												2
S_SOF_Fires_Coord												3
F_CAOC_COD_SOLE_Coord												2
F_CAOC_COD_BCD_Coord												4
F_CAOC_COD_All_Gen_Info	P	O	P	O	P	O	P	O	O	O		11
Room Ownership	1	1	1	1	1	1	1	1	1	1	1	
Active Participation	4	1	5	6	3	3	2	3	2	3	3	
Matrix Participation												
Observing for SA	1	2	2	1	1	2	1	2	3	3	3	

Figure 5. Chat Room Assignments (From Air Force Research Laboratory Warfighter Readiness Division, 2008).

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## **II. BACKGROUND**

Chapter II Background Section A of this thesis is intended to bring the reader up-to-date on the history and types of missions the Air and Space Operations Center (AOC) supports in the battle space. Section B will advise the reader on the internal structure of the AOC and responsibilities of key personnel. Section C will inform the reader on how the AOC Dynamic Targeting Cell (DTC) is designed to handle asymmetric threats and describe specifically how DTCs respond and prosecute time sensitive targets.

### **A. AIR AND SPACE OPERATIONS CENTER**

#### **1. History Behind AOC Conceptualization**

The 11 September 2001 attacks on the World Trade Center and the Pentagon revealed that U.S. homeland security was extremely vulnerable and lacked the procedures for an effective coordinated response to combat such highly coordinated and dynamic attacks. At the time of the 9/11 attacks, North American Aerospace Defense (NORAD) command, a joint endeavor between U.S. and Canada, was responsible for air security and air sovereignty defense for all of North America. NORAD's primary mission at the time of the terrorist attacks only considered the Soviet Union as a major threat and therefore NORAD only trained and planned to combat and respond to over-the-horizon strategic-strike ballistic missile attacks from the Soviet Union. An attack from nineteen terrorists using U.S. hijacked airplanes was never anticipated or planned for which caught NORAD unprepared to respond appropriately. Air Force General Myers, Chairman of the Joint Chiefs of Staff, later defended NORAD's poor response to the 9/11 attacks by stating that NORAD was not tasked or responsible for attacks originating from within the U.S. but only responsible for those attacks that originated from outside the U.S (Banusiewicz, 2004).

According to David Fulghum, a Senior Military Editor for Aviation Week & Space Technology, "a common or single, integrated air picture would let operational commanders or intelligence analysts, for example, follow the flight of a suspicious aircraft as it moves across international borders or from one theater to another."



(Fulghum, 2004, 58). It is expected that integration of AOCs will result in reduced reaction times between AOCs and provide seamless pass off tasking from one AOC to another when disaster strikes.

## 2. AOC Types and Responsibilities

A total of 23 AOC sites have been established on air force bases (AFB) located in the Continental U.S. and in several other countries around the world. Figure 6 shows the locations of all twenty-three AOC sites.

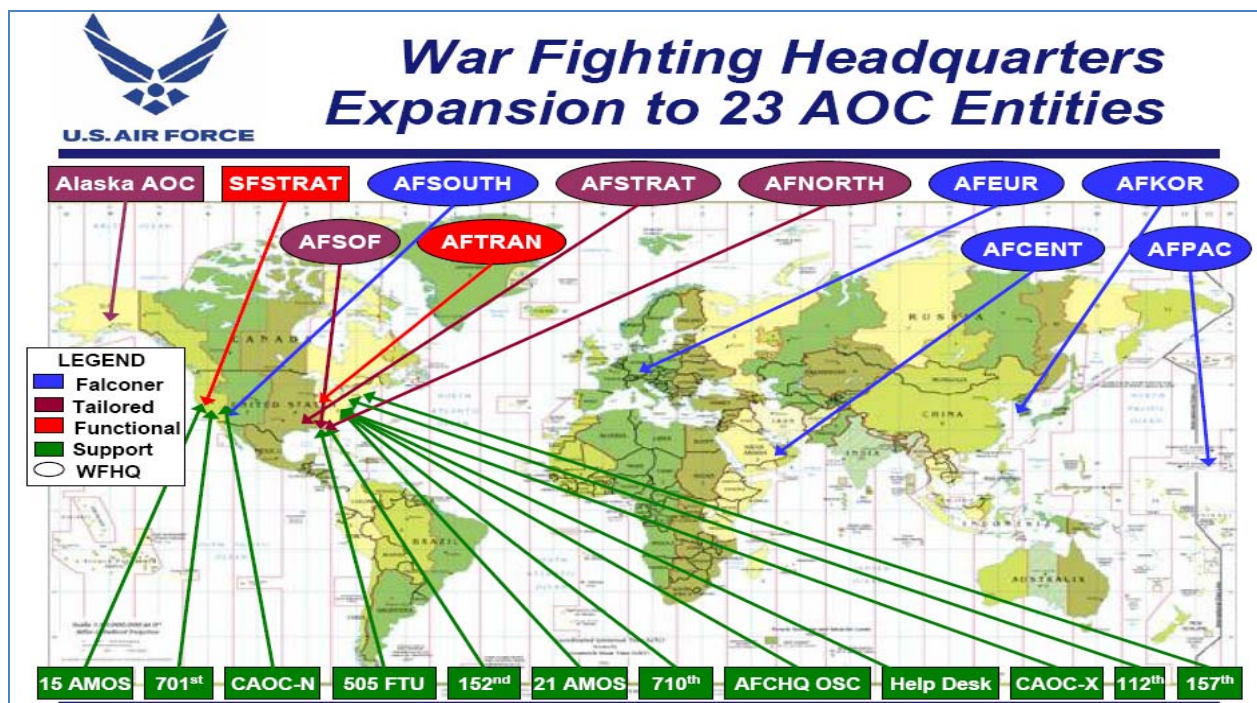


Figure 6. Air and Space Operations Center Location Map. (From Murray, 2008).

AOCs are divided into four different groups according to the type of operational support they provide to the Joint Force Air Component Commander (JFACC). The four groups are Falconer, Tailored, Functional and Support. All AOCs, on short notice, can provide the JFACC with the appropriate air assets and trained personnel needed to respond to threats originating from both inside and outside the continental U.S. Falconer AOCs are responsible for directly supporting their assigned theater regional commander. Tailored AOCs support missions ranging from homeland security to strategic defense. Functional AOCs are tasked with supporting the U.S. Strategic Command and the U.S.

Transportation Command. The other support AOCs across the U.S. undertake roles dealing with training personnel along with various other support related functions.

The push to ensure Commanders have the greatest and newest technology available to them in order to protect the U.S. homeland and our way of life is evident in the integration of AOCs across the country. In May 2007, the dual-hatted Commander of the 12th AF and AFSOUTH opened the first and only U.S. "Falconer" AOC at the time, at Davis Monthan AFB in Arizona. The new AOC is responsible for supporting air and space missions in both Central and South America and in the Caribbean (Jackson & Broshear, 2007). The 1st AF, home based at Tyndall AFB Florida, also opened a new Tailored AOC in June 2007. As a member of the Air Component Command, the 1st AF directs and controls all activities for NORAD within the continental U.S.

### **3. AOCs Designated as a Weapons System**

The AOC was designed as a weapon system by the Chief of Staff of the AF, General Michael E. Ryan, in September 2000. While visiting Hurlburt Field, Florida aerospace operations center, General Ryan had the following to say:

I declare the AOC as an official weapons system today. During a real-world operation, the AOC will be the "eyes, ears, hands and legs of the commander. In each of our theaters, the ability of the air commander to execute the missions he has depends on the capability to have an aerospace operations center that (can be tailored) ... for the mission he needs to do. We need a base lining of the capabilities in that weapons system, just as we do in our capabilities in something like an F-16. (In the F-16), we have a crew chief that knows how to maintain it and we have pilots that know how to fly it. We have to have the same concept for our aerospace operations centers (U.S. Department of Air Force, 2000, 1).

According to the Air Force, the AOC was designated as a weapon system to ensure standardization in the way centers are equipped, employed, and trained (Sirak, 2006). This standardization across AOCs is expected to (1) produce seamless coordination between operators, (2) reduce cost for equipment, (3) decrease compatibility issues between equipment, and (4) provide better personnel training standards.

## B. INTERNAL STRUCTURE OF AOC AND RESPONSIBILITIES

### 1. Internal AOC Organizational Structure

To be operationally effective, all division leaders and internal office personnel must stay abreast of the common operating picture and coordinate with other division personnel in a timely manner. Coordination and collaboration are essential to being able to quickly assess the dynamic situation, develop effective courses of action, and assign appropriate assets to respond to dynamic events. There are several internal divisions within an AOC with each division having specific responsibilities and an assigned leader for coordination. Figure 7 shows the internal AOC organizational divisional structure. During the Research Event, the Senior Operations Duty Officer (SODO), the Senior Air Defense Officer (SADO), the Senior Intelligence Duty Officer (SIDO) and other analysts and key specialty/support personnel (i.e., Marine Liaison, Navy Liaison, Battlefield Coordination Detachment) were actively engaged in the coordination of assets and capabilities. Additionally, the above personnel relayed and inputted critical data and information into the team macrocognition process.

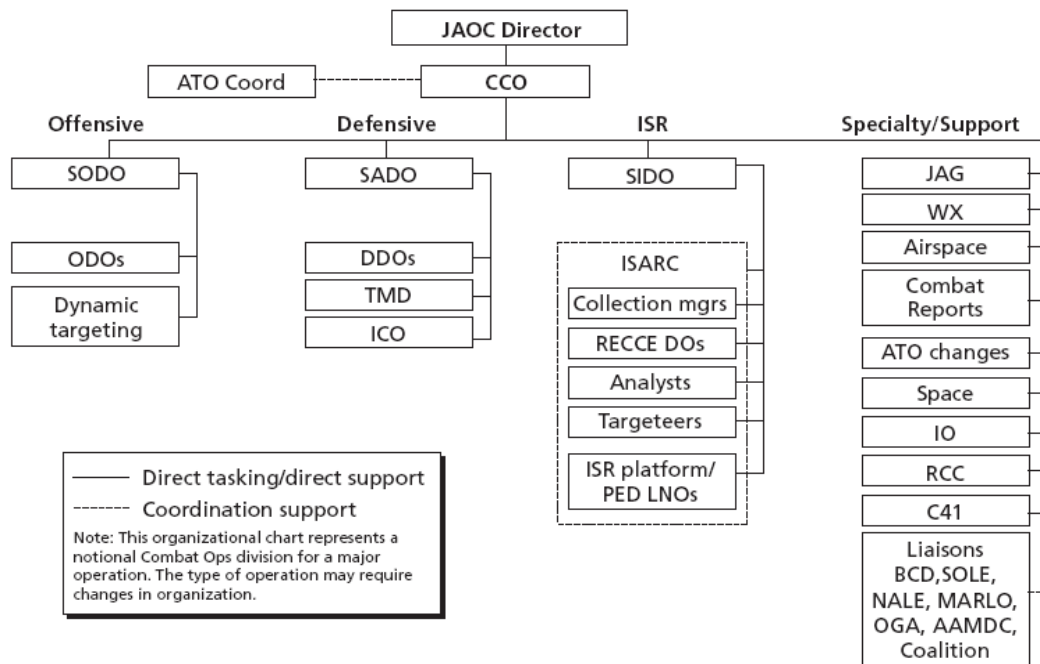


Figure 7. Air and Space Operations Center Internal Organization Structure (From Air Force Tactics, Techniques, and Procedures 2-3.2, 2004).

## **2. Offensive Division and SODO Responsibilities**

The Offensive Division is led by the Senior Operations Duty Officer (SODO) and contains several offensive duty officers and the DTC. The SODO and offensive duty officers are responsible to the Chief of Combat Operations for ensuring that air tasking orders operations meet the JFACC objectives. On-going collaboration with the Wing Operations Center and other service control agencies using the contingency theater automated planning system is necessary to ensure air assets are used effectively to meet objectives. The SODO's specific coordination actions include analyzing air tasking requests to ensure all tasks were attainable; tracking all air tasking order missions and developing of alternate courses of action in case of emergency or change in the common operating picture; and ensuring all changes and modifications to the air tasking order were coordinated with appropriate units and disseminated to all units affected/concerned (12<sup>th</sup> Air Force AFFOR, 1996).

## **3. Defensive Division and SADO Responsibilities**

The Defensive Division is controlled by the Senior Air Defense Officer (SADO) and contains several defense duty officers, theater missile defense, and the interface control officer. The SADO and defense duty officer are responsible to the chief of combat operations for all air defense operations. The SADO and defense duty officer responsibilities include joint planning, coordination, employment and life-cycle management of all air defense systems in the theater. Additionally, they assist in developing courses of action for countering enemy offensive air activities and serve as the airspace control authority developing standard operating procedures for air battle operations. Effective collaboration between the SADO, defensive duty officers, theater missile defense and interface control officer is considered essential to ensure protection of U.S. and ally forces and civilians located within the area of responsibility (Joint Warfare Publication, 2003).

## **4. ISR Division and SIDO Responsibilities**

The Intelligence, Surveillance, Reconnaissance Division (ISRD) is managed by the Senior Intelligence Duty Officer (SIDO) and contains the ISR cell, which employs

several collection managers, analysts, and targeteers. The ISRD is responsible for developing the overall ISR strategy for the AOC and planning and executing ISR missions. Additionally, the ISRD performs detailed assessments and in-depth analysis of the battle space environment and disseminated the information to other Research Event participants. (United States Air Force Central Command, 2008). Figure 8 shows a more detailed list of ISRD assessment and planning functions that must take place in every AOC or training scenario to enable the different internal cells to complete their assigned missions.

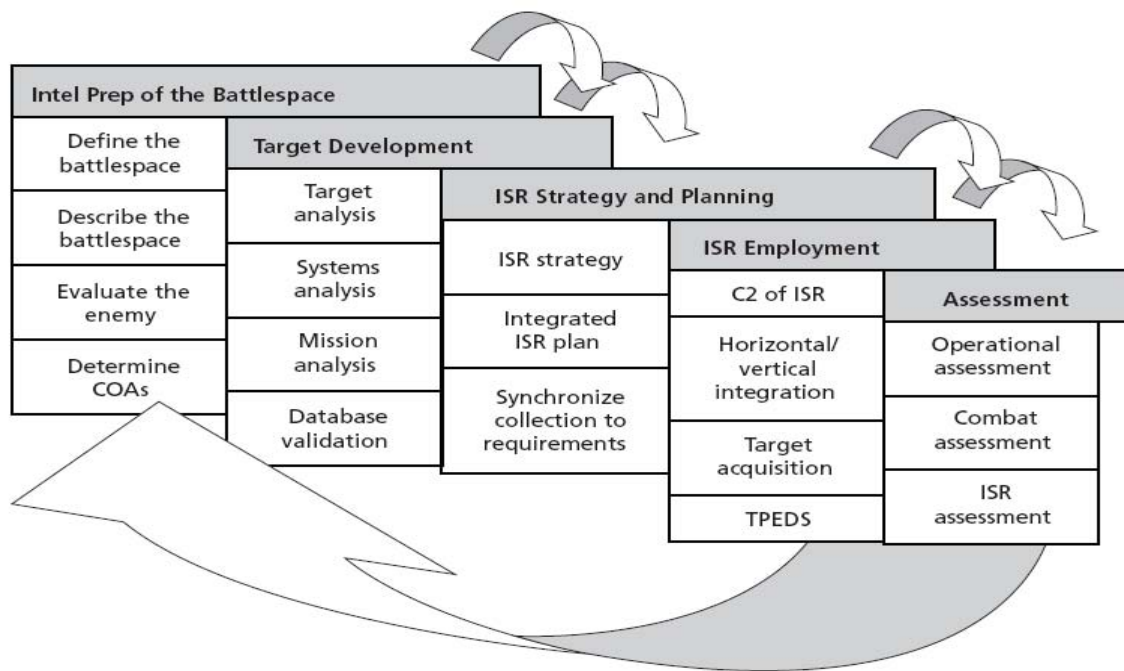


Figure 8. ISRD Assessment and Planning (From United States Air Force Central Command, 2008).

## 5. Specialty/Support Division Responsibilities

Several key personnel in the specialty/support division provide necessary support to AOC internal cells performing live or training missions, such as the JAG Officer, Battlefield Coordination Detachment, Naval Aviation Liaison Element (NALE), Marine Liaison Officer (MARLO), and the Special Operations Liaison Element (SOLE). The JAG Officer provides legal guidance to the internal AOC divisions and operational commanders located in the area of responsibility to assist with rules of engagement

determination. The battlefield coordination detachment is typically an Army assigned liaison officer who is responsible for handling and processing tactical air support and de-conflicting air operations for the Army component in theater. The battlefield coordination detachment assists in planning and coordinating air operations by interpreting and introducing Army ground warfare techniques (Joint Publication 1-02, 2001). The NALE and MARLO liaisons support by planning and coordinating naval and Marine Corp specific capabilities such as air support, ISR capabilities, and amphibious assault operations. The NALE counsels the AOC internal division planners of the maritime domain awareness picture and the MARLO advises the AOC internal division on marine ground specific operations and techniques (12<sup>th</sup> Air Force Air Forces Force, 1996).

## **C. COLLABORATION BETWEEN OPERATIONAL PLAYERS**

### **1. Time Sensitive Target Contributing Factors and Process**

The AOC is tasked with carrying out both static and dynamic operations. Static operations include maintaining the theater common operating picture, developing and analyzing ISR data to maintain accurate situation awareness, supplying weather forecasting services, and providing Judge Advocate General legal services for rules of engagement determination. Dynamic operations can include finding and destroying SCUD missile sites; locating, tracking and destroying radiological or explosively formed projectiles logistic networks; and locating, tracking, and/or exploiting key leadership targets (Air Force Research Laboratory Warfighter Readiness Division, 2008). The method employed by AOCs, depicted in Figure 9, is the Find, Fix, Track, Target, Engage, and Access (F2T2EA) process which enables better command and control decision flow and sensor coordination (Joint Publication 3-60, 2007).

The complexity inherent in performing the tasks involved in static operations coupled with a constantly changing environment of dynamic mission factors (i.e., number of targets, type of targets, and speed of targets) present challenging problems. These extremely challenging problems can be difficult to assess, orchestrate measures and countermeasures, and implement courses of action successfully without having effective

and efficient coordination and de-confliction within the AOC internal organization divisions. Collaboration between the internal divisions is paramount to maintaining an up-to-date situational awareness picture, developing the correct course of action to respond to individual or multiple threats, and assigning the correct weapon to the right mission.



Figure 9. Find Fix Track Target Engage and Asses Dynamic Targeting Model (From Joint Publication 3-60, 2007).

## 2. Dynamic Targeting Cell Responsibilities

The DTC is an optional cell within the AOC and is only stood up under the control of the SODO when there are too many time sensitive targets for the regular AOC internal organization structure to process in a timely and effective manner. The DTC has a minimized chain of command and a streamlined F2T2EA standard operating procedure that supports quicker decision-making and target-prosecution times. The DTC relies heavily on ISR and other information collected from the other internal AOC divisions but



employs a ground track coordinator, an attack coordinator, a command and control duty officer, and a target duty officer. Figure 10 shows the DTC structure in the dashed box.

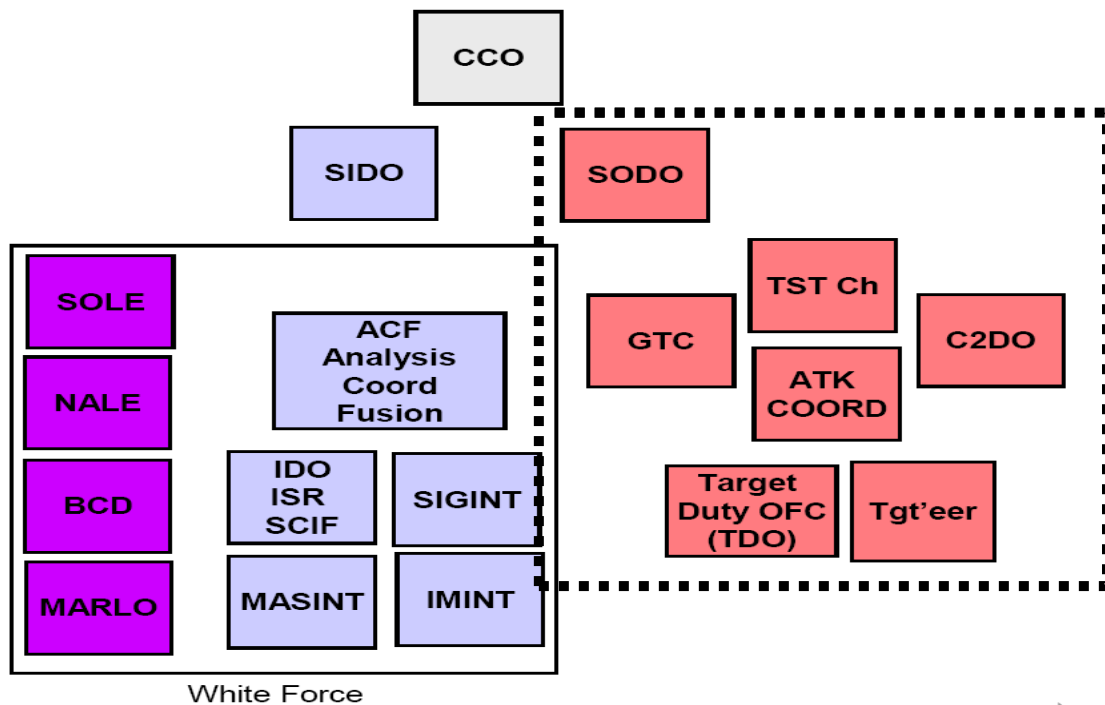


Figure 10. Dynamic Targeting Center Structure (After Case, Koterba, Conrad, Okerman, & Vanderberry, 2006).

During the Research Event, the attack coordinator and target duty officer were responsible for assessing the situation, selecting an appropriate weapon for the target selected, and planning the mission. The attack coordinator also accounted for verifying that the TST target was not on the no strike or no kill list (Shebilski, Freeman, Levchuk, & Gildea, 2008). The command and control duty officer drafts the air tasking orders for all TST missions. To assist with the communication and collaboration between the various DTC and AOC internal division personnel, the joint automated deep operations coordination system collaboration software application tool is used as the primary interface between divisions.



### **3. Find Fix Track Target Engage and Assess Cognitive Processes**

The Air Force uses the F2T2EA, or “Kill Chain” as it is often referred to, to conduct dynamic targeting against TSTs. The kill chain provides AOC decision makers the means by which to quickly engage targets of opportunity. According to the Joint Targeting publication (Joint Publication 3–60, 2007), TSTs are targets of very high importance to the Joint Force Commander’s mission and pose a significant threat to coalition forces. Our enemies today are aware of our tactics, procedures, and asset capabilities and use this knowledge to plot attacks against us. The enemy’s ability to quickly adapt, willingness to hide in caves for long periods of time, and readiness to use civilian populations as human shields, severely challenge the AOC commander’s cognitive processes and ability to effectively apply the F2T2EA targeting steps to counter TSTs.

#### ***a. Step 1 “Find”***

The first step of dynamic targeting is “find.” Based on prior intelligence received, AOC commanders allocate ISR assets to search for TSTs. ISR assets such as airborne warning and control system aircraft, joint surveillance target attack radar system, unmanned aerial vehicles, and reconnaissance aircraft provide the AOC with the most up-to-date intelligence available. The ability to direct and task the often limited and the various types of ISR assets, when and where they are needed, requires skill and is a critical challenge for any commander conducting air operations. It can also be extremely difficult for those analysts responsible for analyzing and trying to decipher the usually large amounts of data. Because ISR assets are needed to support all types of missions, they are not always immediately available when needed. The cognitive processing ability of humans is limited which can make it difficult to process and synthesis the extremely large amount of data and information that is often received. To make matters worse, in order to be effective in a dynamic environment against TSTs, those processing the information must do so on a compressed time-line. The window of opportunity to prosecute TSTs is short and incomplete due to the style of warfare the enemy employs and the decision to act must often be made based on incomplete information.

***b. Step 2 “Fix”***

Fix, the second step in dynamic targeting, refers to the ability to use available ISR assets to locate TSTs (Joint Publication 3–60, 2007). The process of fixing the target involves analyzing data by experienced personnel to provide an accurate picture of the battle space to support AOC commanders in assigning specific sensors at the correct time and intervals. This process can be a long and daunting task because information received from various sensors can often be ambiguous and incomplete. AOC commanders must have the necessary experience to recognize when they have enough information or what additional information they need to support their developing and achieving accurate situation awareness. This task can be a very stressful endeavor for those personnel responsible for asset management and/or making higher level decisions due to the high workload produced by needing to process large amounts of information under severely time compressed conditions with high consequences for failure. The decision maker must be able to deconflict multiple air, land and sea assets, and coordinate and direct ISR assets to collect information on an enemy that is extremely gifted at concealing themselves. Juggling the multiple tasks can produce information overload for decision makers and analysts. Overload consequences can contribute to poor higher-level decisions and poor intelligence collection creating a loss of SA and resulting in greater casualties.

***c. Step 3 “Track”***

Track, the third step in dynamic targeting, starts after a fix is obtained. Assets are then assigned to continually observe and monitor the TST (Joint Publication 3–60, 2007). In a dynamic environment, a TST can change location within minutes. To keep assets tracking the target, decision makers and other personnel involved must maintain accurate SA to be able to immediately react to sudden changes. Maintaining SA requires the decision maker to keep track of multiple processes and events which can tax the operator’s working memory and creates a high cognitive workload. To make the right decisions, the decision maker needs to constantly share information and build new knowledge to stay abreast of the evolving situation. New knowledge is accomplished

through collaboration with other internal and external team members who are analyzing various data sets received from various sensors and then organizing the data into a meaningful structure. Dynamic interactions between personnel responsible for collection and those responsible for information processing must be continuous to ensure the correct sensors are assigned to the right type of targets at the precise time. AOC decision makers must have the ability to process a high volume of information under time-compressed conditions and then make time-critical responses to various situations in stressful environments (high workload, complex socio-technical environment and high consequences for errors).

*d. Steps 4 and 5 “Target and Engage”*

The fourth and fifth steps in the kill chain are target and engage. At this point, the AOC commander has the necessary information to engage and take appropriate actions to cause a desired effect (Joint Publication 3–60, 2007). Even with precise targeting information, other contributing factors, if not properly handled, can cause serious delays and jeopardize the mission. The final decision regarding whether or not to engage a target may also depend on the ability to de-conflict assets in the surrounding area to prevent “blue-on-blue” casualties, determination of rule of engagement authorizing type of attack, and assessment of risk of collateral damage to non-military personnel versus target value. At the conclusion of Operation Desert Storm, 25.6 percent of those killed were due to friendly fire (Krepinevich, 2003). Decision makers must be able to assess the impact of several additional factors on their decision before giving the order or permission to prosecute a TST.

*e. Step 6 “Assess”*

Assess is the sixth and final step in the kill chain. To be effective at this stage, the commander must base his/her decision on the following: how relevant and timely is the intelligence collected; are the right sensors being applied to the right target and at the right time; how effective are the weapons being employed against the TST; and is collateral damage being kept to a minimum? To answer these questions, the commander must be able to direct ISR assets and allocate the correct sensors to conduct

battle damage assessment. Overhead sensors from tactical and national assets provide imagery and other intelligence to help determine the overall state of TST targets after engagement. Based on the battle damage assessment, the AOC commander may decide that the target needs to be placed on the targeting list again or remove it completely from the TST prosecute list. In a dynamic environment, where the information can be incomplete, missing, or overwhelming, challenges to the human cognitive processing ability arise for the decision makers who at a moment's notice must be able to effectively apply the kill chain against a TST (Joint Publication 3-60, 2007).

## **D. TEAM COLLABORATION MODEL**

### **1. Previous Research**

Several previous theses have conducted research to evaluate earlier versions of the ONR developed model of team collaboration. Some of the first field research experiments regarding model evaluation focused on analyzing maritime interdiction operations (MIO) chat logs from three MIO exercises and air warfare audio transcripts from four different teams. A MIO is an operation that attempts to delay, disrupt or destroy an enemy's supply resources before they can be used to harm people or cause other severe damage (Joint Publication 3-03, 2007). The air warfare scenarios involved team collaboration within a shipboard Combat Information Center to identify hostile and friendly air contacts (Hutchins, Kendall, Bordetsky, Bourakov, 2006).

The first structural model of team collaboration validation thesis was done by Ensign Maura Garrity. The thesis involved analyzing the Fire Department of New York communication transcript that recorded several district and regional New York firefighter responses and actions in their response to the September 11, 2001, attacks on the World Trade Center.

A second model of team collaboration thesis was conducted by Lieutenant Commander Catherine Donaldson and Lieutenant David Johnson. The thesis involved analyzing a transcript of recorded audio from the command and control center at NORAD North East Air Defense Sector (NEADS) that recorded communications

between NEADS, the Federal Aviation Administration and other agencies during the events surrounding the discovery of the four hijacked aircraft on September 11, 2001.

A third structural model of team collaboration thesis was conducted by Lieutenant Luis Socias. The thesis analyzed a second communication channel between NEADS, Federal Aviation Administration and other agencies during their response to the discovery of four hijacked aircraft on September 11, 2001.

### **III. LITERATURE REVIEW**

#### **A. COGNITIVE PROCESSES**

The word cognition is derived from the Latin word *cognoscere*, which means “come to know” (Merriam-Webster Dictionary, 2009). An individual usually comes to know by developing and using his or her mental processes such as thinking, knowing and recollection to retain intellectual compilation and gain understanding. Cognition is a process that mainly occurs inside the human brain. The human brain is akin to a central processing unit of a computer. It is instrumental in taking in information from various sources, processing that information, and then storing the information in short-term and long-term memory.

In addition to the basic functions of the brain, the human brain has four primary areas: working memory, attention and performance, visual spatial thinking, and learning recall and long term memory (Schifferstein & Hekkert, 2007). These primary areas are crucial to an individual’s ability to “come to know.” Gaining understanding by an individual or a group of individuals who are functioning together as a team is critical to the individual or team’s ability to effectively perform and solve complex, dynamic problems. Types of cognition include metacognition, macrocognition and microcognition.

##### **1. Metacognitive Processes**

Metacognition can be defined as an individual’s own understanding of his or her cognitive processes and that person’s ability to effectively use that unique understanding as knowledge to improve their cognitive processes (Schifferstein & Hekkert, 2007). In a nutshell, metacognition can be referred to as “thinking about thinking”. An example of metacognition would be that an individual notices that he or she is having a hard time learning event A compared to event B and, therefore, needs to double check event A to ensure comprehension. There are three classes of metacognition: (1) knowledge (i.e., what an individual knows about their own cognitive processes); (2) regulation (i.e., an

individual's own internal mechanisms used to control their cognitive learning); and (3) experiences (i.e., an individual's own experiences with the current cognitive task) (Flavell, 1979).

Individuals who have developed and can exercise sound metacognitive techniques are able to control and focus their learning processes. This can drastically improve their ability to work more effectively and perform increasingly more dynamic tasks. Metacognition is usually measured and evaluated in a laboratory environment by administering a pre-test before the event to test pre-existing knowledge. Then some of the individuals are shown metacognition techniques (Education Resources Information Center Digest, 1990). After the techniques are reviewed, all individuals start participating in the event or scenario. After the event is over, post-tests are administered to all participants and the results between pre-test and post-test are analyzed to determine if metacognition techniques improved the individual's knowledge level and/or over all event performance.

## **2.     Macroognitive Processes**

Macroognition is defined, for this research, as the internalized and externalized high-level mental processes employed by teams to create new knowledge during complex, one-of-a kind, collaborative problem solving (Letsky, Warner, Fiore, Rosen, & Salas, 2007). High-level mental processes refer to the cognitive processes involved in combining, visualizing, and aggregating information to resolve ambiguity in support of the discovery of new knowledge and relationships. Macroognition studies concentrate on assessing complex problems of the naturalistic real world in contrast to microognition studies which are typically focused and limited to laboratory type experiments. Some of the complex problems macroognition studies include making key operational decisions that could affect the lives of individuals under poorly defined situations and under time pressures. Macroognition focuses on both internal and external processes and how they affect the decision maker. Figure 11 shows macroognitive functions and supporting processes that would be used by Dynamic

Targeting Cell (DTC) personnel in executing the Find Fix Track Target Engage and Assess (F2T2EA) process used while prosecuting time sensitive targets (TSTs).

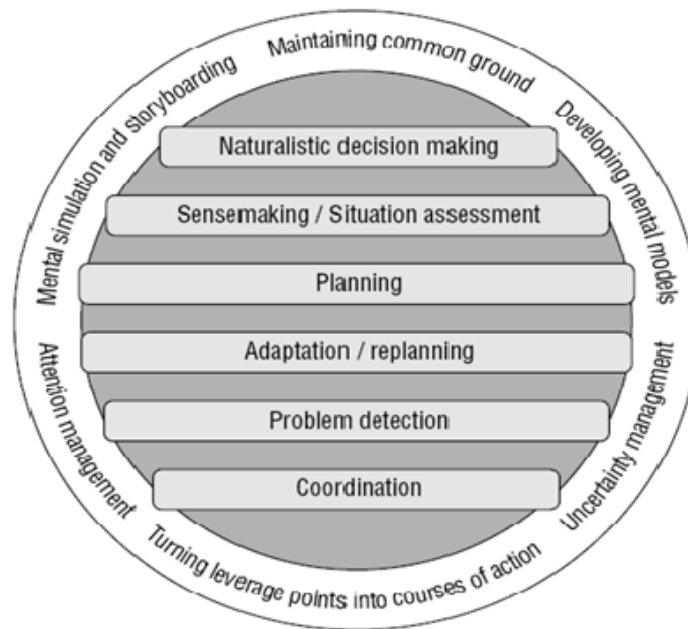


Figure 11. Macrocognitive and supporting processes for individuals, teams, and information technologies (From Klein, Ross, Moon, Klein, Hoffman, & Hollnagel, 2003).

### 3. Microcognitive Processes

Microcognition is recognized as including the essential stepping stones for which thinking and processing are calculated and performed. Memory associated with microcognitive processes allow individual's to cope with more dynamic situations and handle a greater complexity of information processing. Microcognition's primary focus is to try to understand how the invisible processes that transpire inside an individual's brain such as reasoning aptitude and mental processing capability occur and how they are directly affected either favorably or adversely (Klein, Ross, Moon, Klein, Hoffman, & Hollnagel, 2003). Some microcognition experts conduct experiments looking for communication design or team organizational model issues that can negatively impact an individual or team's ability to complete assigned tasks. Poor designs can make it harder on individuals to retrieve important task relevant knowledge (i.e., knowledge bottleneck); remember or store into memory specific key task related details (i.e., memory



bottleneck); and/or make it more difficult to stay focused on the task at hand or switch back and forth from different tasks (i.e., attention bottleneck) (Schifferstein and Hekkert, 2007). Figure 12 shows the situational design interface representing cognitive processes involved. In order to assess microcognition, eye tracking sensors and other measurement devices must be properly designed, implemented, and assessed. The study of microcognition is typically done in a laboratory environment with well defined attributes and goals.

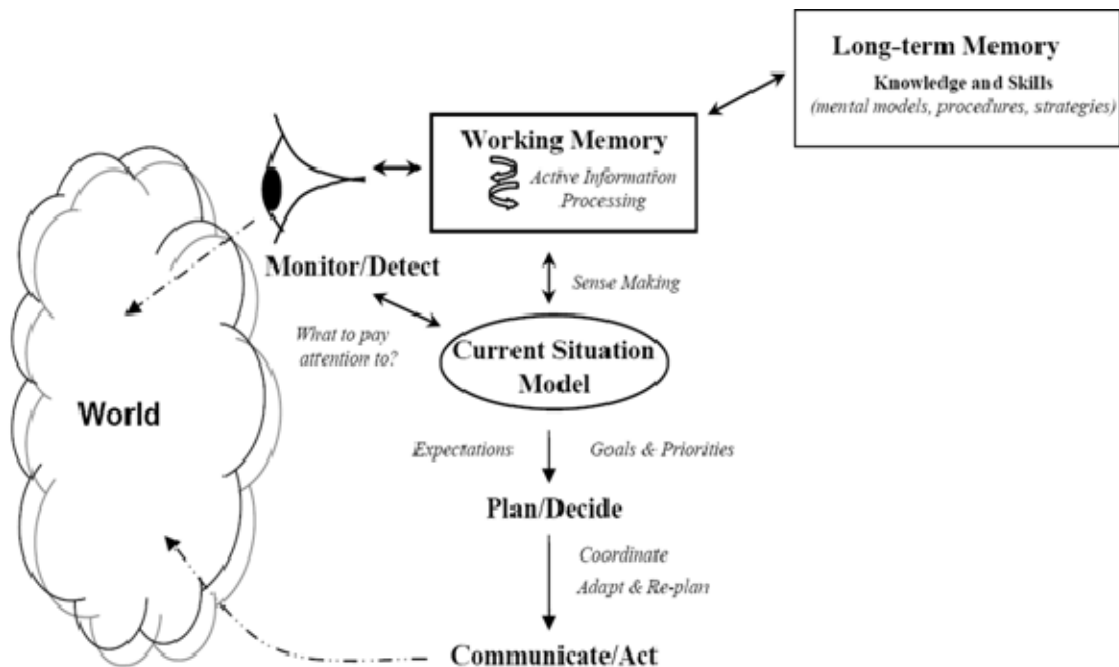


Figure 12. Situational Design and Cognitive Model Process (From U.S. Department of Transportation, 2009).

## B. TEAM PERFORMANCE

### 1. Performance Factors

Performance is defined as an individual's ability to execute one or several tasks with a specific end result (Merriam-Webster Dictionary, 2009). There are several internal and external factors that affect an individual or a group's ability to carry out specific tasks in support of unified missions. Internal factors that affect performance

include individual feelings, emotions, skill level, and inherent core values. External factors include the organizational structure hierarchy (i.e., distributed team, centralized team, etc...), and situational environment factors (i.e., time, space, force and other dynamic elements). Another key factor that can affect performance is the common understood situational awareness between individual teams and team members. In a highly dynamic environment supporting multiple theater operations, it is very easy for an individual to become inundated with too much information leading to information overload resulting in poor decision making. Figure 13 is a performance topology map that shows the relationship between both internal and external factors that affect performance.

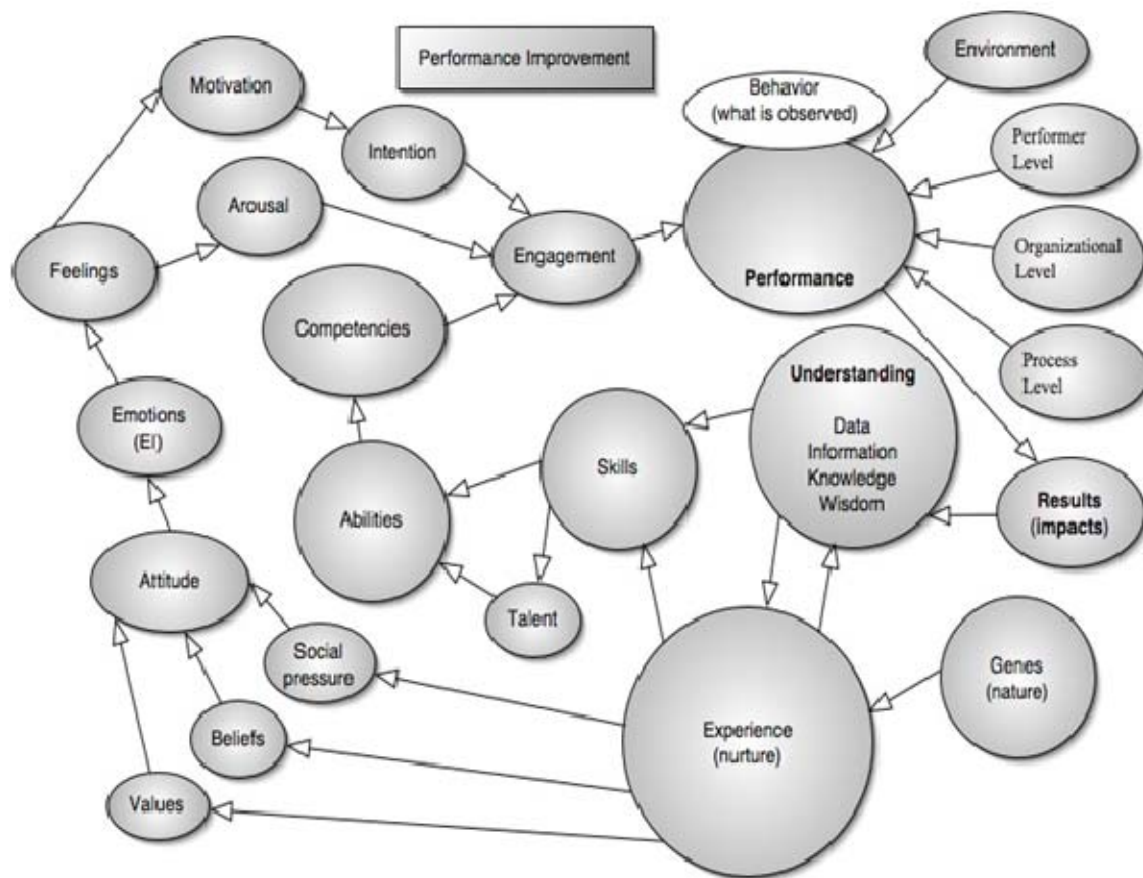


Figure 13. Performance Topology Map (From Clark, 2004).

## **2. Team Performance Metrics and Improvements**

Performance metrics can be established by identifying all the critical processes for accomplishing the individual or team mission objective(s). Next standard operating procedures are developed that are used to accomplish all the identified critical processes. Finally, a value is assigned to each accomplished process based off some variable related to the task (i.e., time of completion, accuracy rating, and communication percentage). These values can then be used as a baseline score that can be compared to other changes made to the system in order to determine if changes in the organizational structure, processing procedures, or human interaction resulted in positive or negative results.

Overall performance can be drastically improved by ensuring that all individuals understand the operational mission objectives and performance goals. Each member should be briefed on common factors to ensure individual mental models are consistent with one another to ensure everyone interprets the goals with the same mind set. Additionally, continued metric studies of the organizational hierarchy and standard operating procedures should be done on a regular basis to make certain the best structural model and procedures are being used to accomplished goals (Nikols, 2003).

## **C. DECISION MAKING**

### **1. Decision-making Methods**

Research in decision making is a long and ongoing process that continues to look at how people make decisions. There are various methods and combinations of decision-making techniques that affect how decisions made. The traditional method of decision making continues to be one of the preferred methods consistently used in both civilian and military environments. According to Orasanu and Connolly, traditional decision makers systematically go through all possible alternatives before choosing the course of action that offers the best outcome. This method for making decisions allows the decision maker to choose their final choice based on known goals, purposes, and values (Klein, Orasanu, Calderwood, & Zsombok, 1993). A more recent decision-making method has been described by Dr. Gary Klein called recognition-primed decision

making. Klein believes that people make decisions much faster and without comparing the choices, as shown in studies of both naturalistic decision making and recognition-primed decision making.

## **2. Classical Approach**

Classical decision making is a cognitive process by which personnel in decision roles follow a step-by-step procedural and/or repeatable way of coming up with the best choice for a given situation. Decision makers arrive at what they feel is the best solution by logically going through a list of choices and weighing the pros and cons of each option and decision before settling on a final choice. The process involves: identifying a set of rules and boundaries of the problem; establishing a procedure or system to evaluate all options; weighting each option outcome against all other option outcomes; and finally, performing a grading of the options. The decision maker will pick the option that provides them with the highest or lowest score depending on how grading rules were setup (Klein, 1999).

According to Beach and Lipshitz, many decision makers resist this classical decision-making method because it is cumbersome and takes lots of the decision maker's time (Klein, et al., 1993). In an experiment conducted at Massachusetts Institute of Technology Sloan School of Management, students in their final year of college were studied to see what decision strategies they would use to select their future job. Surprisingly, students choose to go with their gut feelings rather than sequentially going through the steps to come up with the best choice (Klein, 1999). A similar observation of firefighter commanders, by Klein, operating in stressful environments concluded that firefighters with over twenty years of experience behaved in the same manner as students in the MIT experiment (Klein, 1999).

Although decision makers may use the traditional systematic method in which traditional decision making is performed, classical decision making remains a method that is widely used and is extremely useful in various situations. In a strategic environment, where traditionally time and speed are not critical factors, the classical approach allows the decision makers to take a step back, look at all the different

operational and tactical players involved, consider the various military and political options and implications, weigh the choices against one another, and finally pick the best choice that would minimize casualties and guarantee mission success. Classical decision making also works well at commands that have primary missions of dictating and writing policies.

In a dynamic environment, such as an AOC conducting missions over Iraq and Afghanistan, the classical approach will not work. AOC commanders do not have the time to fully run through all the different possible options before deciding on a course of action. The commander's window of opportunity to engage high-value targets could last for only a few minutes or even only seconds which means the commander must have the necessary training and experience to rapidly decide what are the best techniques and assets to deploy for a given target. Klein referred to decisions made in a time limited environment naturalistic decision making.

### **3. Naturalistic Approach**

Naturalistic decision-making is the “study of how people use their experience to make decisions in field settings” (Klein, 1999). Unlike classical decision making, where decision makers follow an orderly process before finalizing their decision, during naturalistic decision making, decision makers access past experience that applies to the current situation. According to Klein, time pressure, high stakes, experienced decision makers, inadequate information, ill-defined goals, poorly defined procedures, cue learning, context, dynamic conditions, and team coordination are all features that set naturalistic decision making apart from classical decision making (Klein, 1999). Human decision making research conducted by Orasanu and Connolly leads us to believe that the above decision making features (i.e., time pressure) have been left out of past decision making research resulting in an incomplete view into the human decision making process (Klein, et al., 1993).

An AOC commander conducting time-sensitive targeting faces some if not all of the above naturalistic decision-making features. The commander, based on his or her level of experience, must quickly decide on asset allocation and weapons employment for

a given target. Klein estimated that firefighter commanders make 90 percent of their decisions in less than one minute (Klein, 1999). The experience level of the commander plays a major role in their decision making capabilities. Additionally, past mission goals and priorities, rules of engagement limits, reliable intelligence, and predictable casualty rates are other features of importance to the commander. These other features are stored within an experienced commander's memory and are quickly recognized and used in the commander's decision-making process. Klein refers to this as recognition-primed decision making.

#### **4. Recognition-Primed Decision**

Klein, while working with firefighter commanders, noticed that experienced firefighters in a given situation will immediately recognize the most critical factors and then decide and implement the best course of action. The past experience of the commanders immediately takes over and without having to go through a list or comparing possible options, the commander is able to decide and act. To an experienced decision maker, the classical way of coming up with a decision wastes valuable time, which may result in more lives lost and could be the difference between winning or losing the fight. Klein believes that recognition prime decision making is a more strategic and clever way of using one's own experience to quickly come to a decision (Klein, 1999).

Recognition prime decision making is the fusion of a decision maker's use of experience to size up a given situation in order to come up with a course of action and the manner in which he or she mentally simulates implementation of the course of action. The observations and interviewing of experienced firefighters and military decision makers, under time stressed environments, provided Klein with conclusive data on how people use experience to make decision. Klein believes that a decision maker's experience determines his or her course of action and such a decision is normally made without the use of classical decision making techniques (Klein, 1999). Figure 14 is Klein's model on recognition prime decision making. The model shows how an experienced decision maker mentally steps through developing a single course of action.

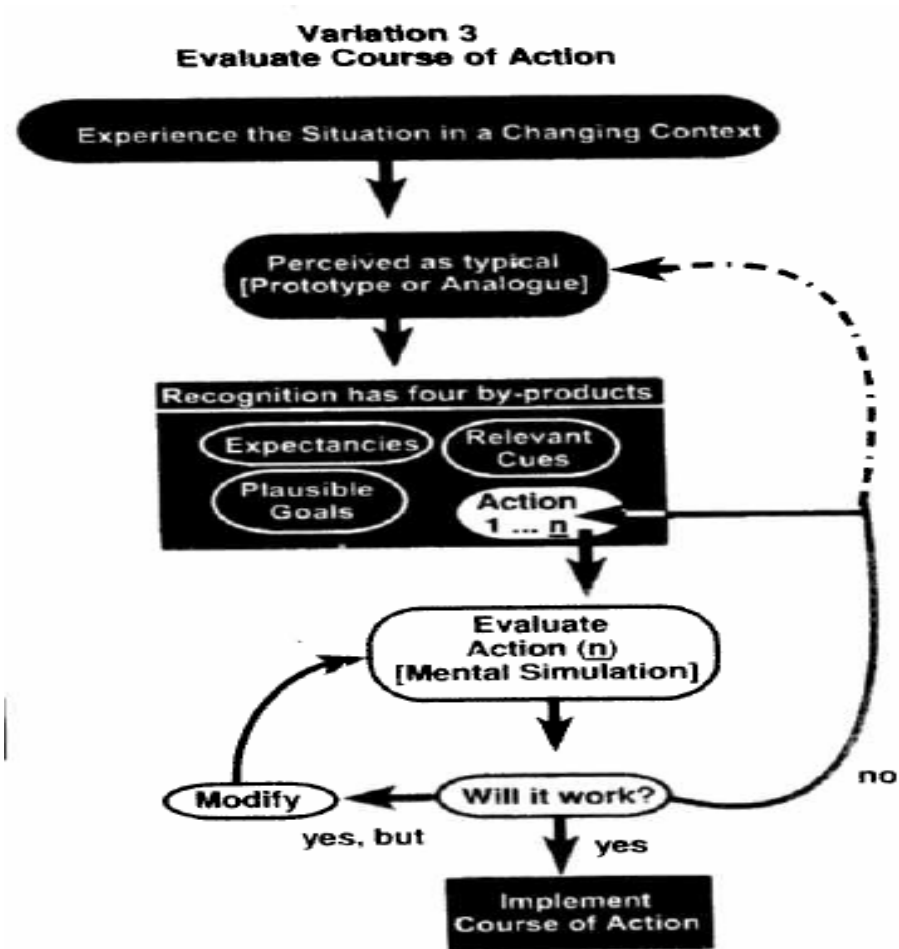
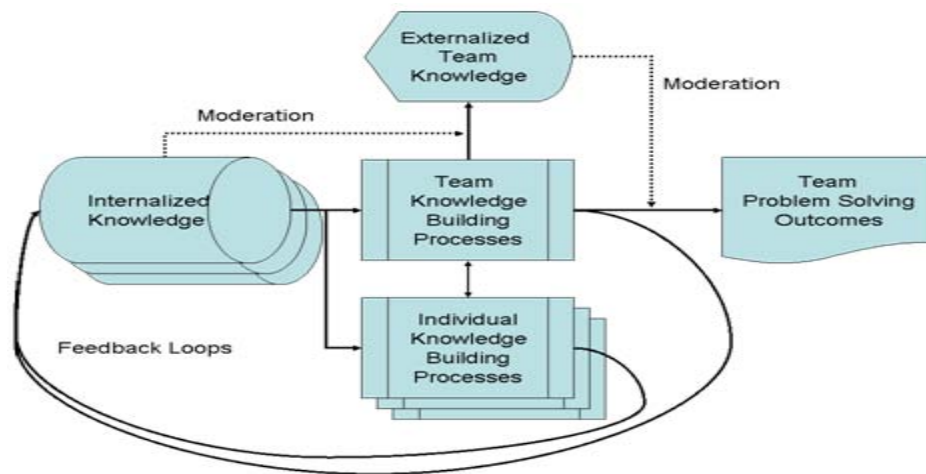


Figure 14. Recognition Prime Decision Model (From Klein, 1993).

## IV. MEASUREMENT MODEL FOR MACROCOGNITION RESEARCH

### A. MODEL MACROCOGNITION FOCUS

The concept of macrocognition is to develop a better understanding of the cognitive processes involved when a team collaborates to solve a unique, complex, time-compressed problem (Letsky et al., 2007). Figure 15 is the team measurement model for macrocognition research that shows the relationship between different phases of knowledge building and developing understanding during team collaboration. This measurement model was developed to try and capture and measure the macrocognitive processes. The term macrocognition was coined to capture and distinguish higher-level cognitive processes used by individuals and teams from lower-level, or microcognitive processes (e.g. attention, perception, and memory) (Letsky et al., 2007).



Legend:



Figure 15. Team Measurement Model for Macrocognition Research (From Fiore et al., in press)



To better understand the relationship between the different phases of the measurement model, shown in Figure 15, one must understand that there is not initial model starting point. Different team dynamics (i.e., personnel, asynchronous team) and assigned tasks will dictate what phase of the model is used. The focus of macrocognition is on building new knowledge in real-world settings when a team collaborates. Figure 16 illustrates how unstructured raw pieces of datum are transformed into integrated actionable knowledge.

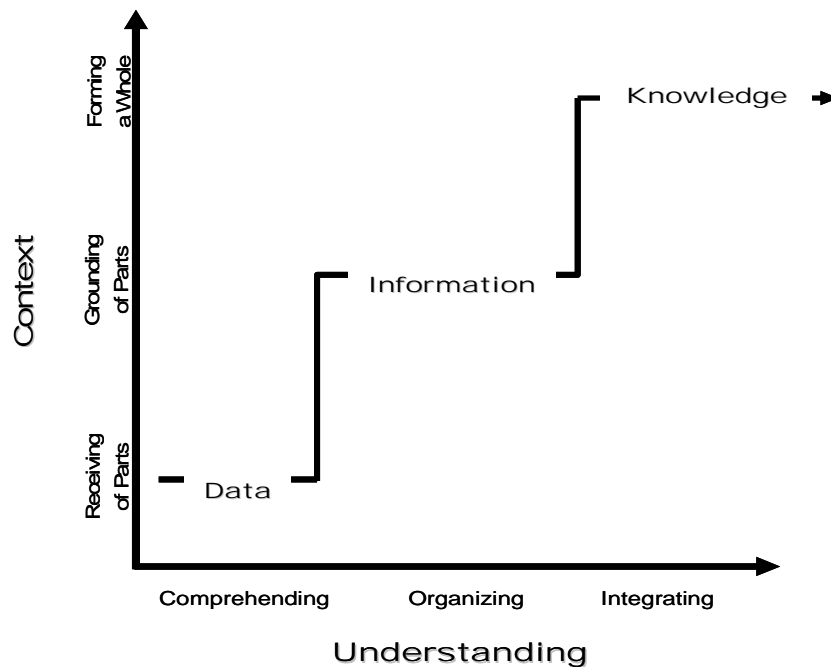


Figure 16. Knowledge Building Process in Macrocognition (From Fiore et al., in press)

Macrocognition is demonstrated during the conversion of internalized team knowledge into externalized team knowledge through the individual knowledge and team knowledge building processes (Fiore, et al., in press,). Data is considered to be raw and unprocessed bits of particulars. For data to be transformed into information, it must be organized and referenced in some context thus being considered processed information. Information is considered to be knowledge when it is organized in such a way that allows it to be understood and used to solve a problem or direct actions. Table 2 provides a formal definition, example and explanation of data, information and knowledge.

Table 2. Data, Information, and Knowledge Definitions (From Fiore, et al., in press).

<b>Concept</b>		<b>Explanation</b>
<b>Data</b>	<i>Definition</i>	Data are disparate statements or facts presented or represented separately and <i>without context</i> .
	<i>Example</i>	“The CH-53 Marine Corps helicopter can hoist 250 feet with a 600 pound lift capacity.”
	<i>Explanation</i>	Here the content is devoid of context and not organized in any way; as such, it is considered only data.
<b>Information</b>	<i>Definition</i>	Information is organized or structured data (i.e., organized or structured statements or facts) that have been <i>related to</i> the problem solving context.
	<i>Example</i>	“The CH-53 Marine Corps helicopter can carry supplies to the Red Cross workers who have been taken hostage,” or, “Our three air vehicles are the CH-53, the F-16, and the E2-C.”
	<i>Explanation</i>	The first example represents a transformation in that it involved connecting the piece of data to the problem. The second example represents a transformation in that it involved organizing the data via categorization such that it can serve the problem solving; resources were organized into categories of resources that serve the problem solving.
<b>Knowledge</b>	<i>Definition</i>	Knowledge is the integration of content from two or more categories of information into something which did not explicitly exist before and which has been made actionable by being related to the problem solving context.
	<i>Example</i>	“The CH-53 Marine Corps helicopter cannot be used to carry supplies because it is foggy over the southwest corridor of Nandor.”
	<i>Explanation</i>	This represents a transformation because vehicle information (a category), was integrated with weather information (another category) in such a way that it serves the problem solving; that is, it was made actionable by explaining when it could get (or not get) supplies to the hostages.

## B. MACROCOGNITIVE PROCESS DEFINITIONS

The focus of the macrocognitive process model and definitions is to measure all macrocognitive processes that occur during a collaborative team problem solving task. The measurement model attempts to understand the related processes between internalized knowledge, individual knowledge building processes, team knowledge building processes and externalized team knowledge macrocognitive phases demonstrated during team collaboration. Data on internalized knowledge is measureable by using eye tracking equipment and conducting calculations on eye gaze. Individual knowledge building data is measurable by collecting observation information. Data on team knowledge building processes is collected through communications and non-verbal

communication gestures (i.e., facial expressions). Externalized team knowledge is collected through communications and actual objects that are created by the team (i.e., maps, charts, and graphs) (Fiore et al., in press). The increased perception and understanding could one day allow researchers to be able to accurately predict the individual and/or group of teams, generated problem solving outcomes.

### **C. STAGES OF THE MEASUREMENT MODEL**

The team measurement model was developed from various iterations of other previous macrocognitive models. The model focuses on measuring the macrocognitive processes engaged in by the team as they build knowledge at the individual and team levels (Fiore, et al., in press). Team collaboration within the measurement model consists of five macrocognitive stages that show how members collaborate with each other and with the team as a whole. In certain stages of the model, information can flow back and forth between each other or skip stages all together. There is no official macrocognitive building block or individual or team information processing starting point for the team measurement model stages as theoretically a team member can start in any model stage. For the purpose of describing the model stages and their interactions, in this thesis we will start by describing the flow of individual and/or team information processes at the internalized team knowledge stage flowing into the individual knowledge building stage unto team knowledge building, externalized team knowledge, and team problem solving outcomes. Further explanation of each cognitive stage and their associated cognitive processing codes are defined in Table 3.

Table 3.           Macrocognitive Stages and Associated Processes included in the Measurement Model (From Fiore et al., in press).

1	<b><u>Stage I: Internalized Team Knowledge Process:</u></b> Refers to the collective knowledge held in the individual minds of team members. Internalized Team Knowledge is measured by eliciting it from individual team members using methods such as card sorting, concept mapping, paired comparison ratings, scenario probes.
a.	<b>Team Knowledge Similarity:</b> Team knowledge similarity can involve the degree to which differing roles understand one another (e.g., how well a land/sea vehicle specialist understands a humanitarian specialist), or how well the team members' understand the critical goals and locations of important resources (shared situation awareness).
b.	<b>Team Knowledge Resources:</b> Team members' collective understanding of responsibilities and resources associated with the task.
2	<b><u>Stage II: Individual Knowledge Building Process:</u></b> is a process which includes actions taken by individuals in order to build their own knowledge. These processes can take place inside the head (e.g., reading, mentally rotating objects) or may involve overt actions (e.g., accessing a screenshot).
a.	<b>Individual Information Gathering:</b> Individual information gathering involves actions individuals engage in to add to their existing knowledge such as reading, asking questions, accessing displays, etc.
b.	<b>Individual Information Synthesis:</b> Individual information synthesis involves comparing relationships among information, context, and artifacts to develop actionable knowledge.
c.	<b>Knowledge Object Development:</b> Knowledge object development involves creation of cognitive artifacts that represent actionable knowledge for the task.
3	<b><u>Stage III: Team Knowledge Building Process:</u></b> is a process which includes actions taken by teammates to disseminate information and to transform that information into actionable knowledge for team members.
a.	<b>Team Information Exchange:</b> Team information exchange involves passing relevant information to the appropriate teammates at the appropriate times.
b.	<b>Team Knowledge Sharing:</b> Team knowledge sharing involves explanations and interpretations shared between team members or with the team as a whole.
c.	<b>Team solution Option Generation:</b> Team solution option generation describes offering potential solutions to a problem.
d.	<b>Team Evaluation and Negotiation of Alternatives:</b> Team evaluation and negotiation of alternatives describes clarifying and discussing the pros and cons of potential solution options.
4	<b><u>Stage IV: Externalized Team Knowledge Process:</u></b> Refers to facts, relationships, and concepts that have been explicitly agreed upon, or not openly challenged or disagreed upon, by factions of the team.
a.	<b>Externalized Cue-strategy Associations:</b> Externalized cue-strategy associations describe the team's collective agreement as to their task strategies and the situational cues that modify those strategies (and how).
b.	<b>Pattern Recognition and Trend Analysis:</b> Pattern recognition and trend analysis is the accuracy of the patterns or trends explicitly noted by members of a team that is either agreed upon or unchallenged by other team members.
c.	<b>Uncertainty Resolution:</b> Uncertainty resolution is the degree to which a team has collectively agreed upon the status of problem variables (e.g., hostile/friendly).
5	<b><u>Stage V: Team Problem Solving Outcomes:</u></b> Are assessments of quality relating to a team's problem solutions or plan.
a.	<b>Quality of Plan:</b> Quality of plan (problem solving solution) involves the degree to which the solution adopted by a problem solving team achieves a resolution to the problem (e.g., limit fatalities, limit destruction).
b.	<b>Efficiency of Planning Process:</b> Efficiency of planning process describes the amount of time it takes a problem solving team to arrive at a successful resolution to a problem.
c.	<b>Efficiency of Plan Execution:</b> Efficiency of plan execution describes the quality of the plan (e.g., number of lives saved) divided by the amount of resources used to accomplish this and the amount of time the plan takes to unfold.

### **1. Internalized Team Knowledge**

The first stage of the measurement model for macrocognition research focuses on Internalized Team Knowledge (ITK) which refers to the overall combined knowledge of each team member (Fiore et al., in press). ITK is collected on individuals by conducting various assessments such as administering tests and surveys to gather past individual experience. The knowledge collected on individuals provides data on the level of team knowledge at different points in time which provides insight into the knowledge building process.

### **2. Individual Knowledge Building**

The second stage of the measurement model focuses on Individual Knowledge Building (IKB). The cognitive process of team members can flow to IKB or to team knowledge building (TKB). IKB actions are actions such as reading or asking questions that can be taken by an individual to increase his or her knowledge (Fiore et al., in press). An individual or the team as a whole asking for more information is a sign that an individual or team members are trying to improve individual situational awareness. To achieve situational awareness, members must take immediate action to correct information deficiency and gain knowledge. To increase their knowledge, team members can either ask other team members for help or obtain outside specific job related knowledge building from schools or training. As the measurement model shows, the feedback loop allows members to seek outside knowledge building.

### **3. Team Knowledge Building**

The third stage, Team Knowledge Building (TKB), is a highly dynamic and iterative process. TKB facilitates information exchange among teammates with the intent to generate a plan or coordinate some type of action (Fiore et al., in press). Actionable information will be processed and disseminated as a solution to team related problems and non-actionable information will remain in the minds of team members as internalized knowledge. A similar process takes place within an AOC targeting cell. Information received on a high-value target may not be used to perform targeting mission. Some

information will be incomplete and require validation through collection from overhead or ground assets. Until further information is collected, unused data will be stored in databases until more information becomes available.

#### **4. Externalized Team Knowledge**

The fourth stage, Externalized Team Knowledge (ETK) is defined as knowledge agreed upon by team members to be factual (Fiore et al., in press). Knowledge held by team members is different from information, because unlike information, agreed upon knowledge is put through processes to ensure accuracy and completeness (Fiore et al., in press). Such processes could range from verifying sources to comparing output from multiple intelligence, surveillance and reconnaissance assets. The intelligence community uses a similar process to ensure information received from various intelligence sources is accurate. Data collected goes through a validation process and is analyzed before the information can be considered as intelligence.

#### **5. Team Problem Solving Outcomes**

During the Team Problem Solving Outcomes, stage potential solutions are assessed to determine if they meet certain criteria of effectiveness (Fiore et al., in press). In a naturalistic environment, AOC target cell members conduct battle damage assessment to measure the effectiveness of weapons used. According to the commander's handbook for Joint Battle Damage Assessment, battle damage assessment is the "timely and accurate estimate of damage resulting from the application of military force, either lethal or nonlethal, against a predetermined objective." By using various combinations of intelligence, surveillance and reconnaissance assets, commanders can measure the performance of their forces and weapons effectiveness against different targets.

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## **V. METHOD**

### **A. EXERCISE DATA SELECTION**

The October 2008 Air Force Research Event scenarios were conducted in six two-hour sessions. On day one and day two, two sessions were executed on each day (one AM and one PM session). On day three and day four, only one session was conducted, and on day four, exercise personnel were debriefed.

Both authors, in conjunction with the thesis advisor determined that the best data for conducting analysis and coding to empirically evaluate the model of team collaboration would be the data generated during the middle four sessions. Our reasoning was based on our expectation that there would be a learning curve on day one as personnel were becoming familiar with the exercise operating environment, procedures, and other exercise personnel operators.

### **B. DATA FORMATTING**

The Air Force Research Event chat logs were presented to us spread out in several tables located in one access database file that was generated from the CAOC Performance Assessment System (CPAS), which was developed by Johns Hopkins University Applied Physics Laboratory to mine data from AOC systems. Exercise chat logs included 15 different internal chat rooms. Both authors extracted the Mardem-Bey Internet Relay Chat log data from a CPAS database access file. Data was pulled from the fifteen different chat logs from (4) two-hour exercise sessions selected for coding. The data was then imported into a Microsoft excel document with four tabs, each labeled and containing the data from the four sessions selected for analysis. Each data set was then organized by specific chat room and then ordered by time of transmission (earliest to latest). Each chat log entry also contains originator and destination chat room information.



### **C. PRACTICE CODING**

Practice coding was completed by both coders utilizing the revised set of macrocognitive process included in the model of team collaboration on 1000 lines of maritime interdiction operation exercise data. Both coders began by coding 100 lines of chat log data separately and then reviewed the coding with the thesis advisor. This initial practice coding and review of additional practice coding on a separate transcript was considered sufficient training to calibrate the coders on the coding process. As a team, we reviewed additional lines of coding along with the definitions and focused the discussion on where coders disagreed on their coding of individual chat log entries. After this review of the initial coded data, the rest of the maritime interdiction operation data was coded separately by the two authors and then reviewed to help ensure the two coders were well calibrated.

### **D. FINAL CODING OF TRANSCRIPTS**

All four selected Research Event sessions were coded separately by the coders. The first 100 lines from the Day One AM data set were coded first. Once completed, the coding was discussed and reviewed with the thesis advisor to ensure macrocognitive process definitions were being applied in a consistent manner. Following this final review and calibration, both coders coded the rest of the Day One AM session and reviewed all coded data to ensure a consistent interpretation of the macrocognitive process definitions. During the review, new codes and definitions that were difficult to interpret/apply were discussed and justified to reconfirm the coding process. The subsequent remaining three exercise sessions were coded separately and then reviewed at the completion of each session prior to moving onto a new session. Again, this was done to discuss any new codes assigned and to discuss the more difficult speech turns. This rigorous process was employed to ensure the Research Event team communications were interpreted correctly and to help ensure a consistent application of the macrocognitive process definitions.

## E. MEASURE OF INTER-RATER RELIABILITY

Both authors coded 2,493 lines of chat log entries contained within the four selected exercise sessions. Once the coding was completed, both coders reviewed the data again to try to resolve differences in some codes assigned to data. After thorough and diligent deliberation, there were some originally assigned codes that were changed to match the other coder's code but not all codes match as there still remained some differences of opinion between code definition interpretations. To determine the overall percentage of agreement between the two coders, the qualitative categorical statistic Kappa Cohen was used to calculate the percentage of agreement between the two coders using the code values assigned by each coder. An additional code was created called the Extra Code Filler (ECF). The ECF code was necessary to ensure that each coder assigned the exact same number of total codes in order to accurately calculate inter-rater reliability for the two coders, using Kappa Cohen. Kappa Cohen is the preferred statistic over the Chi-square statistic as Kappa Cohen tests for agreement where as Chi-square tests for association (Thomas, & Hersen, 2003). Kappa Cohen is a better statistic for measuring categorical items as it accounts for and factors into the calculation that each coder may also agree by chance and not strictly because they chose the same selection option or code. Figure 17 shows the Kappa Cohen statistic. In the Kappa Cohen equation,  $\Pr(a)$  value is the observed agreement among coders and  $\Pr(e)$  is the hypothetical probability of chance agreement.

$$k = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

Figure 17. Kappa Cohen Statistical Equation (From Wikipedia, 2009).

Kappa Cohen has a range of 0 to 1. The larger the value calculated indicates a greater agreement between the two coders. A Kappa Cohen value of .0 to .20 indicates a slight agreement, .21 to .40 indicates a fair agreement, .41 to .60 indicates a moderate

agreement, .61 to .80 a substantial agreement, and .81 to 1 indicates an almost perfect agreement. A Kappa Cohen value of 0 indicates no agreement between coders (Wikipedia, 2009).

To calculate Kappa Cohen, both coders organized the exercise data so there was only one code assigned to each line of chat log text. If one coder did not code a specific line of data, that is, if there was a disagreement between the coders on whether a code should have been assigned, the ECF code was used to ensure each coder assigned the same total number of codes. The macrocognitive process definitions were assigned a numerical value for each code (i.e., Administrative = 1, Miscellaneous = 2, Team Information Exchange = 3, etc.) and then a 15x15 contingency table was filled out using the coder assigned codes. A 15x15 table was needed and used during our coding process as we assigned 15 different codes to our data. Figure 18 shows a sample 3x3 contingency table to illustrate the calculation process:

Rater #2	Rater #1		
	"y"	"r"	"c"
"y"	9	3	1
"r"	4	8	2
"c"	2	1	6

Figure 18. Sample 3x3 Contingency Table (From University Nebraska 2009).

In Figure 18, the diagonal cells of the matrix indicate agreement between the coders whereas the other cells and associated values indicate the difference between what each of the coders chose. In the matrix, both raters agreed 9 times on "y", 8 times on "r", and 6 times on "c". By totaling column 1 and row 1, you can deduce that rater 1 selected "y" 15 times and rater 2 chose "y" 13 times. By totaling all the column values or rows you can find the total number of codes assigned per rater. In the matrix above, 36 codes were assigned.

To determine  $Pr(a)$  in the Kappa Cohen equation for the above matrix, one takes the diagonal values 9, 8, and 6 (sum 23) and divides by 36, which is the total number of codes assigned, where the result is  $Pr(a) = .6389$ . To find  $Pr(e)$ , one must determine the percentage of times rater 1 and rater 2 chose “y”, “r” and “c” individually and multiply the “y”, “r”, and “c” percentages against one another and sum the results. For the above matrix, rater 1 chose “y” 15 times out of 36, resulting in .4167 percent, “r” 12 times out 36, resulting in .3333 percent, and “c” 9 times out of 36, resulting in .25 percent. Rater 2 chose “y” 13 times out 36, resulting in .3611 percent, “r” 14 times out 36, resulting in .3889 percent, and “c” 9 times out of 36, resulting in .25 percent. Rater 1 “y” times rater 2 “y” = .1505. Rater 1 “r” times rater 2 “r” = .1296. Rater 1 “c” times rater 2 “c” = .0625. By adding up the percentages .1505, .1296, and .0626,  $Pr(e)$  equal .3426. Therefore,  $k$  is calculated as .4507, which indicates rater 1 and rater 2 have a moderate inter-rater reliability of agreement.

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## VI. RESULTS

### A. CODING RESULTS

#### 1. Code Definitions and Interpolation

The Research Event was analyzed and coded as four individual event sessions. The analyzed classified Appendix 1 data is retained in the classified section of the Naval Postgraduate School Dudley Knox Library. The first session's data contained 528 entries of text, session two through contained 625, 668, and 672 entries of text, respectively. Total entries of text analyzed and assigned codes were 2,493. Session text consisted of anywhere from a 1 word statement to a 40 word paragraph. Most entries, based on macrocognitive complexity and number of utterances, were assigned multiple codes. For the 2,493 lines of text analyzed, 3,158 codes were assigned by each coder. These codes represent the cognitive processes used during the Research Event. Each coder analyzed the text one line at a time and assigned a code for each line of text. This process was necessary, along with the use of the Extra Code Filler codes to ensure equal distribution of codes between coders when there was a disagreement on whether a code should or should not be assigned, to facilitate the calculation of inter-rater reliability. Research Event coded speech turn examples are listed in Table 4 along with their associated measurement model code definition.

Table 4. Measurement Model Macrocognitive Process Code Definitions and Research Event Coded Examples.

1	<b><u>Stage I: Internalized Team Knowledge Process:</u></b> Refers to the collective knowledge held in the individual minds of team members. Internalized Team Knowledge is measured by eliciting it from individual team members using methods such as card sorting, concept mapping, paired comparison ratings, scenario probes.
	<b>Team Knowledge Similarity:</b> Team knowledge similarity can involve the degree to which differing roles understand one another (e.g., how well a land/sea vehicle specialist understands a humanitarian specialist), or how well the team members' understand the critical goals and locations of important resources (shared situation awareness).  <i>- No Coded examples for AOC data</i>

	<p><b>Team Knowledge Resources:</b> Team members' collective understanding of resources/responsibilities associated with the task.</p> <ul style="list-style-type: none"> <li>- <i>I remember sketchy authentication codes</i></li> <li>- <i>Fighter aircraft #2 is out of position, looks like other strike assets are quicker</i></li> <li>- <i>He wouldn't request to return to base (RTB), he tells you he is RTB</i></li> </ul>
2	<p><b>Stage II: Individual Knowledge Building Process:</b> is a process which includes actions taken by individuals in order to build their own knowledge. These processes can take place inside the head (e.g., reading, mentally rotating objects) or may involve overt actions (e.g., accessing a screenshot).</p>
	<p><b>Individual Information Gathering:</b> Individual information gathering involves actions individuals engage in to add to their existing knowledge such as reading, asking questions, accessing displays, etc.</p> <ul style="list-style-type: none"> <li>- <i>What is the correct way to pass tasking to a predator to attack?</i></li> <li>- <i>Joint coordinating elements do you know the local threat/ risk in the area and do you have imagery of the locations?</i></li> <li>- <i>Any battle damage assessment reports/imagery post-strike for aircraft?</i></li> </ul>
	<p><b>Individual Information Synthesis:</b> Individual information synthesis involves comparing relationships among information, context, and artifacts to develop actionable knowledge.</p> <ul style="list-style-type: none"> <li>- <i>Reliable sources report a known country bomb component supplier is awaiting a large shipment of explosives</i></li> <li>- <i>It is suspected that a certain country uses this location as a storage facility for spent fuel.</i></li> </ul>
	<p><b>Knowledge Object Development:</b> Knowledge object development involves creation of cognitive artifacts that represent actionable knowledge for the task.</p> <ul style="list-style-type: none"> <li>- <i>No Coded examples for AOC data</i></li> </ul>
3	<p><b>Stage III: Team Knowledge Building Process:</b> is a process which includes actions taken by teammates to disseminate information and to transform that information into actionable knowledge for team members.</p>
	<p><b>Team Information Exchange:</b> Team information exchange involves passing relevant information to the appropriate teammates at the appropriate times.</p> <ul style="list-style-type: none"> <li>- <i>Target priority coordinated, entered and pushed to joint time sensitive targeting manager</i></li> <li>- <i>The actual snatch and grab would be possibility for special operation force (SOF) but we would need intelligence assistance</i></li> <li>- <i>For your information, this area is now under SOF control. Reconnaissance aircraft to provide over watch, SOF is now in contact with aircraft</i></li> </ul>

	<p><b>Team Knowledge Sharing:</b> Team knowledge sharing involves explanations and interpretations shared between team members or with the team as a whole.</p> <ul style="list-style-type: none"> <li>- <i>Self defense applies for hostile acts from one country airspace to another</i></li> <li>- <i>Enemy forces that employ ordnance, electronic attack or achieve a radar lock against friendly forces have committed a hostile act.</i></li> </ul>
	<p><b>Team Solution Option Generation:</b> Team solution option generation describes offering potential solutions to a problem.</p> <ul style="list-style-type: none"> <li>- <i>Awaiting radiological impact assessment on watershed if strike building.</i></li> <li>- <i>Second option in work is destroy local roads to prevent access in/out.</i></li> <li>- <i>If we crater the runway and taxiways, we may be able to effectively stop the target.</i></li> <li>- <i>To shorten timeline for tactical tomahawk we can launch to loiter.</i></li> <li>- <i>will attempt to mitigate with weaponneering</i></li> </ul>
	<p><b>Team Evaluation and Negotiation of Alternatives:</b> Team evaluation and negotiation of alternatives describes clarifying and discussing the pros and cons of potential solution options.</p> <ul style="list-style-type: none"> <li>- <i>Just throwing this out there, but if you target the roadways, is there a chance you could spook them and they might fire off their missiles and run?</i></li> </ul>
4	<p><b><u>Stage IV: Externalized Team Knowledge Process:</u></b> Refers to facts, relationships, and concepts that have been explicitly agreed upon, or not openly challenged or disagreed upon, by factions of the team.</p>
	<p><b>Externalized Cue-strategy Associations:</b> Externalized cue-strategy associations describe the team's collective agreement as to their task strategies and the situational cues that modify those strategies (and how).</p> <ul style="list-style-type: none"> <li>- <i>The dynamic effect cell chief stated that if there is an erect launcher in a joint special operations area the "rule of engagement" is to kill it as soon as possible and if there is time to de-conflict with the teams</i></li> <li>- <i>He mentioned tomahawk land attack missile (TLAM) wouldn't be de-conflicted either, but I dispute that logic. First, we wouldn't use a TLAM shot to kill a launcher I don't think. Unless it was a last resort.</i></li> <li>- <i>Can get special operation force Team to location as additional resource if we elect to monitor the site for any potential leadership meetings that may occur later</i></li> </ul>
	<p><b>Pattern Recognition and Trend Analysis:</b> Pattern recognition and trend analysis is the accuracy of the patterns or trends explicitly noted by members of a team that is either agreed upon or unchallenged by other team members.</p> <ul style="list-style-type: none"> <li>- <i>Looks like this target may be similar to our first target with regards to unknown presence of Radiological containers in facility. We would look at interdiction for containment to prevent travel to/fm that site, your thoughts on best plan/option</i></li> </ul>



	<p><b>Uncertainty Resolution:</b> Uncertainty resolution is the degree to which a team has collectively agreed upon the status of problem variables (e.g., hostile/friendly).</p> <p><i>- Tomahawk land attack missile most definitely have to be de-conflicted even for over flight of the joint special operations area unless direct otherwise by the Joint Force Commander</i></p>
5	<p><b><u>Stage V: Team Problem Solving Outcomes:</u></b> Are assessments of quality relating to a team's problem solutions or plan.</p> <p><i>- No Coded examples for AOC data</i></p>
	<p><b>Quality of Plan:</b> Quality of plan (problem solving solution) involves the degree to which the solution adopted by a problem solving team achieves a resolution to the problem (e.g., limit fatalities, limit destruction).</p> <p><i>- No Coded examples for AOC data</i></p>
	<p><b>Efficiency of Planning Process:</b> Efficiency of planning process describes the amount of time it takes a problem solving team to arrive at a successful resolution to a problem.</p> <p><i>- No Coded examples for AOC data</i></p>
	<p><b>Efficiency of Plan Execution:</b> Efficiency of plan execution describes the quality of the plan (e.g., number of lives saved) divided by the amount of resources used to accomplish this and the amount of time the plan takes to unfold.</p> <p><i>- No Coded examples for AOC data</i></p>

During our coding of the data, both coders came across certain speech turns that did not adequately represent one of the definitions in the measurement model. To properly represent the data via assigning codes, it was necessary for us to use non-measurement model codes to represent certain speech turns. Table 5 lists the non-measurement model codes and associated definitions that were necessary to cover gaps between the measurement model codes and the session data.

Table 5. Non-Measurement Model Codes/Definitions and Air Force Research Event Coded Examples.

	<p><b><u>Administration:</u></b> Codes necessary for exercise support but not relevant or pertinent to the exercise scenarios.</p> <ul style="list-style-type: none"> <li>- <i>Test</i></li> <li>- <i>In the future, please post reports in "Intel-Report"</i></li> <li>- <i>Cancel that</i></li> <li>- <i>Command and control information posted to folder</i></li> <li>- <i>Chat check</i></li> </ul>
	<p><b><u>Miscellaneous:</u></b> Codes that did not include a macrocognitive process but were part of normal closed-loop communications.</p> <ul style="list-style-type: none"> <li>- <i>Copy, please note request for information</i></li> <li>- <i>Roger on target location</i></li> <li>- <i>Roger, thank you</i></li> <li>- <i>SIDO, standby, checking</i></li> <li>- <i>Copy and standby for additional informational</i></li> </ul>
	<p><b><u>Course of Action:</u></b> Action given that when implemented will significantly affect the scenario outcome.</p> <ul style="list-style-type: none"> <li>- <i>Contact fighter aircraft #12 on circuit #2 for clearance to drop weapons.</i></li> <li>- <i>Move aircraft to provide over watch for Special Operation Force teams</i></li> <li>- <i>You can move fighter aircraft #2 and #10 to training camp located in the vicinity of of city #3 and city #5. Upon completion of mission, return to current location</i></li> <li>- <i>Plan is to strike unless directed otherwise</i></li> <li>- <i>Move aircraft to investigate IED implantation report</i></li> </ul>
4	<p><b><u>Request to Take Action:</u></b> Lower-level action request between peers that most likely would not affect the scenario outcome.</p> <ul style="list-style-type: none"> <li>- <i>Please instruct aircraft #1 to observe possible SCUD hiding site</i></li> <li>- <i>Please pass report to all</i></li> <li>- <i>Need you to check with air combatant commander and special operations commander for teams in area</i></li> <li>- <i>Recommend kinetic destruction target</i></li> </ul>

## 2. Percentage of Codes

The measurement model for macrocognitive research includes 18 macrocognitive process definitions which facilitate the categorization and measurement of macrocognition demonstrated in teams. Analysis of the Air and Space Operations Center (AOC) dynamic effects cell (DEC) communications revealed that during the October Research Event, 13 out of 18 measurement model macrocognitive processes were used during the exercise. Additional non-measurement codes such as Administrative (ADMIN), Miscellaneous (MISC), Course of Action (COA) and Request Take Action (RTA) were assigned to cover gaps in the measurement model codes and our Research Event data. Table 6 presents percentage of macrocognitive processes including administrative, miscellaneous, and Extra Code Filler codes.

Table 6. Macrocognitive Process Code Percentages including Administrative, Miscellaneous and Extra Code Filler.

Code	Macrocognitive Process Categories				
Individual Knowledge Building		Coder 1 #	Coder 2 #	Coder 1 %	Coder 2 %
IIG	Individual Information Gathering	537	526	17.00	16.66
IIS	Individual Information Synthesis	72	33	2.28	1.04
KOB	Knowledge Object Development	0	0	0.00	0.00
Team Knowledge Building					
TIE	Team Information Exchange	1192	1187	37.75	37.59
TKS	Team Knowledge Sharing	209	172	6.62	5.45
TSOG	Team Solution Option Generation	19	11	0.60	0.35
TENA	Team Evaluation and Negotiation of Alternatives	12	4	0.38	0.13
TPPR	Team Process and Plan Regulation	0	0	0.00	0.00
Internalized Team Knowledge					
ITK-TKS	Team Knowledge Similarity	2	1	0.06	0.03
ITK-TKR	Team Knowledge Resources	4	2	0.13	0.06
IK	IK - Interpositional Knowledge	3	1		
ISA	ISA - Individual Situational Awareness	1	1		
Externalized Team Knowledge					
ECSA	Externalized Cue-Strategy Association	12	4	0.38	0.13
PRTA	Pattern Recognition and Trend Analysis	4	0	0.13	0.00
UR	Uncertainty Resolution	1	0	0.03	0.00
Problem Solving Outcomes					
QOP	Quality of Plan	0	0	0.00	0.00
EPP	Efficiency of Planning Process	0	0	0.00	0.00
EPE	Efficiency of Planning Execution	0	0	0.00	0.00
Decision to Take Action					
COA	Course of Action	154	149	4.88	4.72
RTA	Request Take Action	81	87	2.56	2.75
Administrative, Miscellaneous, Statistical					
MISC	Miscellaneous Actions/Comments	666	670	21.09	21.22
ADMIN	Administrative Actions/Comments	185	185	5.86	5.86
ECF	Extra Code Filler	8	127	0.25	4.02
				100.00	100.00

Table 6 presents the recalculated percentages using each coder's individual code assignments and using Extra Code Filler codes which ensured both coders assigned the exact same number of codes. Table 7 percentages were calculated using only the coder's individual code assignments. Coder 1 assigned 2,299 codes and coder 2 assigned 2,176 codes.

Table 7. Macrocognitive Process Code Percentages excluding Administrative, Miscellaneous and Extra Code Filler.

Code	Macrocognitive Process Categories				
Individual Knowledge Building		Coder 1 #	Coder 2 #	Coder 1 %	Coder 2 %
IIG	Individual Information Gathering	537	526	23.36	24.17
IIS	Individual Information Synthesis	72	33	3.13	1.52
KOB	Knowledge Object Development	0	0	0.00	0.00
Team Knowledge Building					
TIE	Team Information Exchange	1192	1187	51.85	54.55
TKS	Team Knowledge Sharing	209	172	9.09	7.90
TSOG	Team Solution Option Generation	19	11	0.83	0.51
TENA	Team Evaluation and Negotiation of Alternatives	12	4	0.52	0.18
TPPR	Team Process and Plan Regulation	0	0	0.00	0.00
Internalized Team Knowledge					
ITK-TKS	Team Knowledge Similarity	2	1	0.09	0.05
ITK-TKR	Team Knowledge Resources	4	2	0.17	0.09
IK	IK - Interpositional Knowledge	3	1		
ISA	ISA - Individual Situational Awareness	1	1		
Externalized Team Knowledge					
ECSA	Externalized Cue-Strategy Association	12	4	0.52	0.18
PRTA	Pattern Recognition and Trend Analysis	4	0	0.17	0.00
UR	Uncertainty Resolution	1	0	0.04	0.00
Problem Solving Outcomes					
QOP	Quality of Plan	0	0	0.00	0.00
EPP	Efficiency of Planning Process	0	0	0.00	0.00
EPE	Efficiency of Planning Execution	0	0	0.00	0.00
Decision to Take Action					
COA	Course of Action	154	149	6.70	6.85
RTA	Request Take Action	81	87	3.52	4.00
				100.00	100.00

Table 7 reflects overall code percentages after removing the extraneous codes administrative, miscellaneous and extra code filler codes. Administrative and miscellaneous communications were prevalent throughout the exercise but do not represent a cognitive process therefore that type of communications falls outside the scope of analysis for this thesis. The most frequently assigned codes, as shown in Table 6 were Team Information Exchange, 37 percent, miscellaneous, 21 percent, and Individual Information Gathering, approximately 17 percent. Table 7 shows the

recalculated percentages of the macrocognitive processes used when the administrative, miscellaneous, and ECF codes were removed from the calculations. Team Information Exchange, 53 percent, and Individual Information Gathering, 24 percent, had the highest usage. After removing the extraneous codes, the Decision to Take Action (combination of Course of Action and Request Take Action codes) encompasses approximately 11 percent of the communications and Team Knowledge Sharing makes up about 8 percent of coded communications.

### **3. Code Trends**

One of our main assumptions before analyzing and coding the Research Event data was that there would be a need for a tremendous amount of information sharing amongst internal and external team members and a lot of information gathering by individual team members required to appropriately fix, find, track, target, engage and asses dynamic targets. After removing the extraneous codes assigned to the dynamic targeting center data, the percentages (shown in Table 7) indicate that approximately 53 percent of the data was coded as Team Information Exchange and approximately 24 percent was coded as Individual Information Gathering. Roughly 77 percent of the coded data is attributed to information gathering or information relay which validated our main assumption of large amounts of information sharing and passing.

Another assumption that we had regarding the data is that more information gathering would take place earlier in the exercise in order for individuals to build an initial mental picture and become familiar with exercise and associated scenario parameters. Table 8 shows the number of Individual Information Gathering codes assigned across the four day exercise. Contrary to our original assumption, exercise day 4 produced the most Individual Information Gathering codes of approximately 160 compared to a previous high of roughly 135 codes that was assigned to exercise day 2 data.

Table 8. Individual Information Gathering Day 1-4 Totals.

Individual Information Gathering		
	Coder 1	Coder 2
Day #1	107	103
Day #2	139	133
Day #3	131	131
Day #4	160	159
Total	537	526

After studying the Research Event indoctrination and exercise preparation guide and further analyzing the data on day 4, we attributed the higher coding percentage to be a result of multiple dynamic scenarios being run on day 4. This resulted in the participants needing to clarify and gather more information than on the previous three days. Additionally, the Research Event planners did a solid job on preparing the exercise participants by conducting an INCHOP brief and reviewing the Research Event indoctrination and exercise preparation guide with all participants prior to the start of the exercise. This resulted in less need for the participants to share and gather initial information. Table 9 shows Team Information Exchange from day 1 compared against day 4 which also supports this claim.

Table 9. Team Information Exchange Day 1 and Day 4 Totals.

Team Information Exchange		
	Coder 1	Coder 2
Day #1	225	235
Day #4	313	317

Another assumption was that there would be more Decisions to Take Action codes (combination Course of Action and Request Take Action codes) occurring later in the Research Event. This initial assumption was based on the way most typical exercises are developed to build upon a climatic end point requiring several decisions to be made

typically near the end of the exercise. Table 10 lists the number of Course of Action and Request Take Actions codes assigned throughout the four day exercise.

Table 10. Course of Action and Request Take Action Day 1 through Day 4 Totals.

Course of Action		
	Coder 1	Coder 2
Day #1	23	20
Day #2	42	43
Day #3	42	42
Day #4	47	44
Total	154	149

Request Take Action		
	Coder 1	Coder 2
Day #1	15	13
Day #2	27	34
Day #3	22	23
Day #4	17	17
Total	81	87

The code numbers indicate that scenarios on day one and day four required the least decision making and that day 2 and day 3 consistently required approximately the same amount of Course of Action and Request Take Action.

#### 4. New Codes and Modifying Definitions

During the practice coding process, it was determined by both coders that the new set of macrocognitive process definitions included in the model failed to appropriately address and specifically define all the cognitive processes for the data that was analyzed. Specifically, there were no macrocognitive process definitions under the new set of definitions that appropriately classified or defined exercise personnel's decision to take action. Decisions to Take Action were classified into two sub-categories, Course of Action and Request Take Action. Course of Action was assigned to a speech turn that issued an order for a more significant action that would be more likely to affect the

overall scenario outcome. An order usually was issued from a more key position or senior person down to a lower level position or subordinate. Request Take Action was assigned to speech turns that were lower-level requests between peers to take some action, but would not likely affect the entire outcome of the scenario. Other codes that were assigned but not part of the set of macrocognitive process definitions are miscellaneous and administrative. Miscellaneous codes were assigned to speech turns that did not include a macrocognitive process but were part of normal closed-loop communications such as “Roger”. Administrative codes were assigned to speech turns that were necessary for exercise support but not relevant or pertinent to the exercise scenarios such as communications checks prior to start of the exercise.

## **B. INTER-RATER RELIABILITY**

Table 11 is a pivot table that compares coder 1 codes against coder 2 codes. Coder 1 codes are read down and coder 2 codes are read across. Coder matches run diagonally through the pivot table starting with code Administrative 183, Miscellaneous 663, Team Information Exchange 1134, Individual Information Gathering 521, Individual Information Synthesis 23, Externalized Cue-Strategy Association 4, Team Knowledge Sharing 136, Course of Action 138, Request Take Action 78, Team Solution Option Generation 6, Team Evaluation and Negotiation of Alternatives 3, Internalized Team Knowledge 3, Uncertainty Resolution 0, Pattern Recognition and Trend Analysis 0, and Extra Code Filler 0.



Table 11.      Coder Pivot Table

CODE TITLE	ADMIN	MISC	TIE	IIG	IIS	ECSA	TKS	COA	RTA	TSOG	TENA	ITK	UR	PRTA	ECF	Total Coder 2
ADMIN	183	0	0	0	0	0	1	0	0	0	0	0	0	0	1	185
MISC	0	663	6	0	0	0	0	1	0	0	0	0	0	0	0	670
TIE	0	1	1134	5	9	1	24	9	0	2	0	0	0	1	1	1187
IIG	2	0	2	521	0	0	1	0	0	0	0	0	0	0	0	526
IIS	0	0	4	0	23	0	6	0	0	0	0	0	0	0	0	33
ECSA	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	4
TKS	0	0	17	1	6	1	136	3	0	3	3	1	0	1	0	172
COA	0	0	4	1	0	0	1	138	1	1	0	0	0	0	3	149
RTA	0	0	4	1	0	0	1	0	78	0	0	0	0	0	3	87
TSOG	0	0	1	0	1	2	0	0	0	6	1	0	0	0	0	11
TENA	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	4
ITK	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
UR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRTA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECF	0	2	20	8	33	4	39	3	2	6	5	2	1	2	0	127
Total Coder 1	185	666	1192	537	72	12	209	154	81	19	12	6	1	4	8	3158

The pivot table also illustrates what codes the coders disagreed upon. Under the Administrative (ADMIN) category, coder 1 and coder 2 both had assigned a total of 185 administrative codes to the data. However, both coders only matched selections for 183 out of 185 administrative codes. There were two disagreements per each coder. Reading down the column under ADMIN you can see that coder 2 had selected two Individual Information Gathering (IIG) codes when coder 1 had assigned administrative codes. Additionally, reading across the row for category ADMIN, you can see that coder 1 selected 1 Team Knowledge Similarity (TKS) and 1 Extra Code Filler (ECF) code when coder 2 had assigned an ADMIN code. Reasons for disagreement between coders can be attributed to a particular line of text not being interpreted the same way

between the coders (i.e., coder 1 thought the line of text related to the actual exercise whereas coder 2 classified it as non-essential communications assigning an administrative code).

One thing that stands out after going through each code category above and comparing the common differences between coders (i.e., when one coder chose X the other coder chose Y) is that when there was a disagreement on Team Information Exchange (TIE) or Team Knowledge Sharing (TKS) codes, the other code typically selected code was Team Knowledge Sharing and Team Information Exchange (respectively). Reading down the pivot table for category TIE, you can see that the number of agreed Team Information Exchange codes is 1,134 and that coder 2 disagreed with coder 1 and selected Team Knowledge Similarity 17 times. Additionally, reading down Team Knowledge Sharing (TKS) category, both coders agreed 136 times but coder 2 disagreed and selected Team Information Exchange 24 times. The disagreement between TKS and TIE and the patterned alternative response of the other coder code indicates that there is some ambiguity in the measurement model definition for both codes. Furthermore, when coder 1 selected Team Information Exchanges and Team Knowledge Sharing, coder 2 disagreed and selected the Extra Code Filler (ECF) code 20 and 39 times (respectively). This disagreement between coders and non selection of the measurement model code indicates that the definitions for Team Knowledge Sharing and Team Information Exchange need to be modified to remove ambiguity and vagueness.

### **1. Kappa Cohen Statistic Analysis**

Kappa was calculated using the equation listed in Figure 19. Probability of Agreement,  $Pr(a)$ , is calculated by adding up all the agreements of the fifteen codes used and dividing that number by the total codes assigned.  $Pr(a) = (183 + 663 + 1134 + 521 + 23 + 4 + 136 + 138 + 78 + 6 + 3 + 3 + 0 + 0 + 0) / 3158 = .915769474$ . Probability of Agreement Due to Randomness,  $Pr(e)$ , is calculated by multiplying coder 1 categorical codes against coder 2 categorical codes (i.e., ADMIN \* ADMIN, MISC \* MISC, etc.), summing the total and dividing that number by the total codes times the total codes.  $Pr(e) = (185 * 185 + 666 * 670 + 1192 * 1187 + 537 * 526 + 72 * 33 + 12 * 4 + 209 *$

$172 + 154 * 149 + 81 * 87 + 19 * 11 + 12 * 4 + 6 * 3 + 1 * 0 + 4 * 0 + 8 * 127) / (3158 * 3158) = .225355972$ . Figure 19 shows the calculation of the Kappa Cohen equation using our statistic numbers.

$$k = \frac{\text{Pr}(a) - \text{Pr}(e)}{1 - \text{Pr}(e)} = \frac{.915769474 - .225355972}{1 - .225355972} = .891265507 \approx .89$$

Figure 19. Kappa Cohen Statistical Equation Result.

Our .89 returned Kappa value indicates that coder 1 and coder 2 both interpreted the measurement model definitions and Research Event data the same way. A returned kappa (k) value ranging between .81 – 1 is considered an almost perfect agreement between coders (Landis & Koch, 1977).

## C. COGNITIVE PHASES

### 1. First Stage Macrocognitive Phase

Prior to being assigned to an AOC, service members are often interviewed and have their professional records screened to ensure the member has the adequate formal schooling, training and experience level to successfully perform AOC tasks. Based on the type of training and level of experience, team members assigned to an actual AOC or just participating in a coordinated exercise, bring different levels of knowledge that can be applied to various dynamic situations. In the first stage of the measurement model, this existing knowledge is referred to as Internalized Team Knowledge. According to the measurement model, Internalized Team Knowledge is the knowledge held in the mind of an individual team member. Our coding of the Research Event communications data revealed that only .15 percent of the total data coded was Internalized Team Knowledge. Internalized Team Knowledge consists of two cognitive process subcategories called Team Knowledge Similarity and Team Knowledge Resources.

Team Knowledge Similarity looks at how well team members in different jobs within the AOC understand each other's roles and responsibilities. A generic example of Team Knowledge Similarity would be how well does the intelligence officer understand

the role of the JAG officer. Team Knowledge Resources focuses on the team's overall collective understanding of the task (SUMMIT Measurement Model Document). Coded Research Event communication data did not provide any definitive reasons that explained the team member's low usage of the Internalized Team Knowledge cognitive process. The specific reason for the low usage may lie in further explanation of the Internalized Team Knowledge definition. According to the Salas et al, raw data associated with internalized knowledge should be collected prior to the start of the exercise on all team members and then an after exercise assessment survey should be given to see how well they understood their responsibility and the overall task.

It is not clear whether the above listed pre- and post-assessments were conducted, and no such data has been collected or sent to the coders. Without the pre- and post-assessment data, it is not possible for us to ascertain team members true Internalized Team Knowledge and understanding of roles and tasks by solely looking at the Research Event coded data. It is not fair to say that the low score of Internalized Team Knowledge cognitive processes coded by us is a true and accurate representative of team members overall internalize knowledge. However, evaluation of previous iterations of the SUMMIT model using Northeast Air Defense Sector and Federal Aviation Administration communications data from September 11, 2001 by Luis F. Socias also reflected similar low Internalized Team Knowledge usage and coded scores.

## **2. Second Stage Macrocognition Phase**

Individual Knowledge Building, the second cognitive process in the measurement model, focuses on the actions taken by team members to increase their overall knowledge of a given situation. Even with years of training and schools, individuals may find themselves in situations that require other steps be taken to build on their existing knowledge. According to the SUMMIT definitions, such steps could involve but are not limited to reading and asking questions. Table 12 includes excerpts from the Air Force Research Event showing team members engaging in Individual Information Gathering (IIG) and Individual Information Synthesis (IIS). This includes asking for clarification on information previously passed, such as the name of a missing airfield to requesting specific data on a known bomb maker.

Table 12. Individual Knowledge Building: Individual Information Gathering and Individual Information Synthesis Examples.

<b>Individual Knowledge Building</b>		
<b>Originator</b>	<b>Communication</b>	<b>Code</b>
C2DO	SIDO: I missed the name of the airfield?	IIG
C2DO	SIDO: Type of aircraft we are looking for and its latitude and longitude?	IIG
SIDO	Airfield is located at (*Removed*); type of aircraft is STOL cargo plane.	TIE/TIE
SODO	Command control duty officer (C2DO), what is the capability to track STOL Cargo aircraft with (Tac C2)?	IIG
SIDO	C2DO, STOL cargo aircraft has departed to the target; may operate between 44 and 200 knots.	IIS

<b>Individual Knowledge Building</b>		
<b>Originator</b>	<b>Communication</b>	<b>Code</b>
IOT	NTI: What can you tell me about bomb supplier #1?	IIG
NTI	Information operations targeteer, bomb supplier #1 is a known materials supplier; communication on cover and will report any new intelligence when available.	IIS/TIE

The percentage of Research Event team member speech turns coded as Individual Knowledge Building was 16.66 percent. Individual Knowledge Building was the second most used macrocognitive process. The most used cognitive process was Team Knowledge Building. Although there is no definitive answer, the high usage of Individual Knowledge Building may have resulted from the unfamiliar dynamic setting of the exercise. The Research Event placed team members in a time-compressed situation while at the same time requiring processing of a large amount of information from various intelligence sensors. To build on their existing knowledge and to maintain continuous situation awareness in the dynamic environment, team members engaged in building their individual knowledge by asking lots of questions. High Individual Knowledge Building speech turns were also recording in the Federal Aviation

Administration and Fire Department of New York communication data during the September 11, 2001 attack. This was probably attributed to the unfamiliar and changing environment factors.

### 3. Third Stage Macrocognition Phase

The third cognitive phase of the measurement model is Team Knowledge Building. Team Knowledge Building includes actions taken by team members to disseminate and transform information into actionable knowledge. In a dynamic environment, to be effective against time-sensitive targeting, AOC team members must be ready at all times to make tough decisions in a time limited environment. Speech turns during the Research Event shows that team members were highly engaged in information exchange and sharing. In Table 13, team members discussed the effects of radiological fallout from a possible strike against a building. Such collaboration among different dynamic cells could ensure higher situation awareness and facilitates better informed decision making.

Table 13. Team Knowledge Building: Team Information Exchange Example.

Team Knowledge Building Process		
Originator	Communication	Code
DEC	Awaiting radiological impact assessment on watershed if the building is to be strike. Second, option in work is to destroy local roads to prevent access in/out.	TIE/TSOG
DECD	Aircraft returns watershed non-issue	TIE
JOC_JCE	Dynamic effect cell, you have high-value target on your dynamic target list. What is the air combat commander game plan? If you have a good one, I will appoint you the lead but I think SOF needs to be considered.	TIE/IIG

Forty-three percent of the Research Event team communications were coded as one of the macrocognitive processes that occur during the Team Knowledge Building cognitive processing phase. Macrocognitive processes that were used among the team include Team Information Exchange, Team Knowledge Sharing, Team Solution Option Generation, and Team Evaluation and Negotiation of Alternatives. Most frequently used

macrocognitive processes used were Team Information Exchange (37.57%) and Team Knowledge Sharing (5.45%). Other Team Knowledge Building macrocognitive processes used during the exercise fell below 1 percent. The high usage of Team Information Exchange was probably due to the dynamic nature of the exercise and the complexity involved in engaging time-sensitive targets. Table 14 is an excerpt from the Research Event communications data that shows team members sharing information on rules of engagement and discussing the effects of a strike mission against an airfield.

Table 14. Team Knowledge Sharing Example.

<b>Team Knowledge Building Process</b>		
<b>Originator</b>	<b>Communication</b>	<b>Code</b>
DEC	Self defense applies for hostile acts from Country #3 fighters in Country # 2 or #4 airspace	TKS
DEC	Enemy forces that employ ordnance, electronic attack or achieve a radar lock against friendly forces have committed a hostile act	TKS
TDO	If we crater the runway and taxiways, we may be able to effectively stop the target.	TSOG
IOT	Target Duty Officer (TDO): Just throwing this out there, but if you target the roadways, is there a chance you could spook them and they might fire off their missiles and run?	TENA

#### 4. Fourth Stage Macrocognition Phase

Externalized Team Knowledge refers to knowledge that has been agreed upon by members of the team and is the fourth macrocognitive phase in the measurement model. Under the Externalized Team Knowledge phase, Research Event team members used all three macrocognitive processes: Externalized Cue-Strategy Association, Pattern Recognition and Trend Analysis, and Uncertainty Resolution. The percentage of speech turns coded as one of the macrocognitive processes that occur in the Externalized Team Knowledge phase was only.24 percent with ECSA and PRTA being the most used out of

the fourth stage. Table 15 contains excerpts from the Research Event showing team members coming to an agreement on the type of weapon to use and the de-confliction needed.

Table 15. Externalized Cue Strategy Association and Pattern Recognition Trend Analysis Examples.

<b>Externalized Team Knowledge</b>		
<b>Originator</b>	<b>Communication</b>	<b>Code</b>
DECSOLE	The dynamic effects cell chief stated that if there is an erect launcher in a joint special operations area (JSOA) his rules of engagement (ROE) are to kill it as soon as possible and if there is time to de-conflict with the teams.	ECSA
JSOFT	Correct, if per joint force commander (JFC)	TIE
DECSOLE	I can't remember ROE in the west for OIF but I think it was something similar.	TIE
DECSOLE	He mentioned tomahawk land attack missiles (TLAM) wouldn't be de-conflicted either, but I dispute that logic. First, we wouldn't use a TLAM to shot a launcher...I don't think. Unless it was a last resort.	ECSA
SECSOLE	Second the flight time is great enough to pass the warning and do the de-confliction.	TIE
JSOFT	TLAMs most definitely have to be de-conflicted even for over flight of the JSOA, unless directed otherwise by the JFC. He's not the JFC. If any issues, let me know and I'll pass up to the joint special operation task force commander for discussion with the JFC.	UR/ ECSA
DEC	looks similar to our first target with regards to unknown presence of Radiological containers in facility. We would look at interdiction for containment to prevent travel to/fm that site, your thoughts on best plan/option	PRTA

There is no definitive answer to explain why Externalized Team Knowledge communications, the process where the team validates information for accuracy and completeness before taking action, came in with such low percentages. Our attempt to explain the low Externalized Team Knowledge percentage is that most AOC personnel have years of experience and are trained to do their job with little or no assistance.



Individual cells and operators communicated via chat with other team members after most of the analyses and final agreement on information received was already decided upon or completed. Due to the layout of the Research Event, exercise personnel located in one room with divider walls between each position, it is highly probable that team members communicated with each other via voice vice utilizing chat only, which could have resulted in loss of possible Externalized Team Knowledge speech turns. According to the measurement model definitions, a voice recorder should be used to capture the exchange of information between teammates.

## **5. Fifth Stage Macrocognition Phase**

The final macrocognitive phase in the measurement model is Team Problem Solving Outcomes. During the coding of the data, there was no Team Problem Solving Outcomes cognitive processes found or coded. Team Problem Solving Outcomes focuses on the quality and speed by which team members come up with viable solutions to problems or develop response plans. Our possible explanation of why there were no Team Problem Solving Outcome speech turns is that the team members were dealing with unique dynamic situations which made it difficult to pull from past experiences and possibly which could have made exercise participants feel uncomfortable to suggest and/or recommend solutions. Additionally, Team Problem Solving Outcomes could have been communicated via voice to team members located in same room vice being sent via chat.

## **VII. CONCLUSION AND RECOMMENDATIONS**

### **A. CONCLUSIONS**

#### **1. Use of Codes**

The use of the Research Event communication data to evaluate the measurement model shows that throughout the exercise team members used 13 of the 18 macrocognitive process codes. Codes not used fall within three of the macrocognitive stages of the measurement model. Those not coded include quality of plan, efficiency of planning process, efficiency of planning execution, knowledge object development, and team process and plan regulation. The fact that they were not coded by us does not mean that they did not take place within the exercise. What it means is that the manner by which these processes are captured was not possible when analyzing the Research Event communication chat room data. In other words, these codes not used by us require data to be recorded, time stamp, or be shown graphically so as to measure the outcome and object development of the team.

#### **2. Code Percentage and Kappa Cohen Results**

The code percentage results and the Kappa Cohen analysis assisted in empirically evaluating the SUMMIT measurement model for macrocognitive research. The use of 13 of the measurement model codes is evident throughout the four analyzed exercise sessions. The high, almost perfect, Kappa Cohen result further indicates that both coders had a clear interpretation of the measurement model code definitions and assigned the codes consistently throughout the coding process.

### **B. RECOMMENDATIONS**

We recommend trying to locate or collect other DTC data from future exercises in addition to reanalyzing past maritime interdiction operation and 9/11 Fire Department data using the measurement model for macrocognitive research. Analyzing and coding other data sets using the same measurement model for macrocognitive research will allow side by side comparisons of number of macrocognitive codes used in team collaboration.

The comparative analysis can aid in identifying gaps between the measurement model code definitions and the macrocognitive processes of individuals and teams during real-world scenarios, compared to laboratory experiments. Data could support modifications to the measurement model code definitions or lead to new codes being added (i.e., Request Take Action, Course of Action).

Recommend taking past and future DTC and maritime interdiction operation data and re-calculate/calculate inter-rater reliability between coders using Kappa Cohen. The data generated from the Kappa Cohen process (i.e., pivot chart indication of non agreement between coder assigned codes) is extremely useful in determining if code definitions are too vague. Adjustment of code definitions and recoding and calculating inter-rater reliability can be a metric for testing definition ambiguity and if adjustment aided or worsened the agreement level.

Recommend that pre-exercise coordination be achieved with the exercise director prior to the next Air Force Research Event. Pre-coordination could allow for the use of better macrocognition measurement tools and techniques that would be instrumental in capturing more macrocognitive processes information. Devices such as voice recorders could be used on the main exercise floor to capture exercise personnel speech turns that were spoken due to proximity of other exercise personnel vice being sent as text entries through Mardem-Bey Internet relay chat communications system. Pre-survey and post-surveys could also be administered to exercise personnel that would help in determining if new knowledge was actually generated and/or produced during Individual Knowledge Building and Team Knowledge Building phases. Use of eye tracking equipment could be incorporated at every exercise participant workstation to track their eye movement leading to information collection and possible development of better command and control graphical user interface systems.

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